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AERO/SPACE ENGINEERING

REVIEW OF CURRENT AND FUTURE TRENDS IN AIRCRAFT • MISSILES • ROCKETS • SATELLITES • SPACECRAFT

In this issue

CHARTING THE FUTURE

Editorial, page 25

MAY | 1959

Hard to see, harder to hit, the Rheem AN/USD-2 surveillance drone slips over hostile positions to show a closeup of enemy activities to battlefield commanders. In this high performance drone, the most advanced components are compressed into the smallest, most economical vehicle. Outstandingly successful in recent Signal Corps tests, the AN/USD-2 has already demonstrated range, utility, versatility remarkable in a vehicle of its size.

Miniaturization and component reliability is exemplified by the AN/USD-2's piston engine's fuel pump. Designed and built by Eastern Industries, this precision instrument is capable of delivering 0.4 gpm at 5.0 psi — yet takes up less space than a two-cell flashlight, weighs less than a pound without motor. Utterly reliable, it pumps a precisely calibrated flow of fuel to the powerplant—keeps the drone in the sky and on the lookout.

Eastern high speed gear pumps are small, light in weight — offer the widest performance range: speeds to 24,000 RPM, flow from .025 gpm to 2.0 gpm, pressures from 0 to 2000 psig. Weights with motor range from 1.5 to 8.5 lbs.

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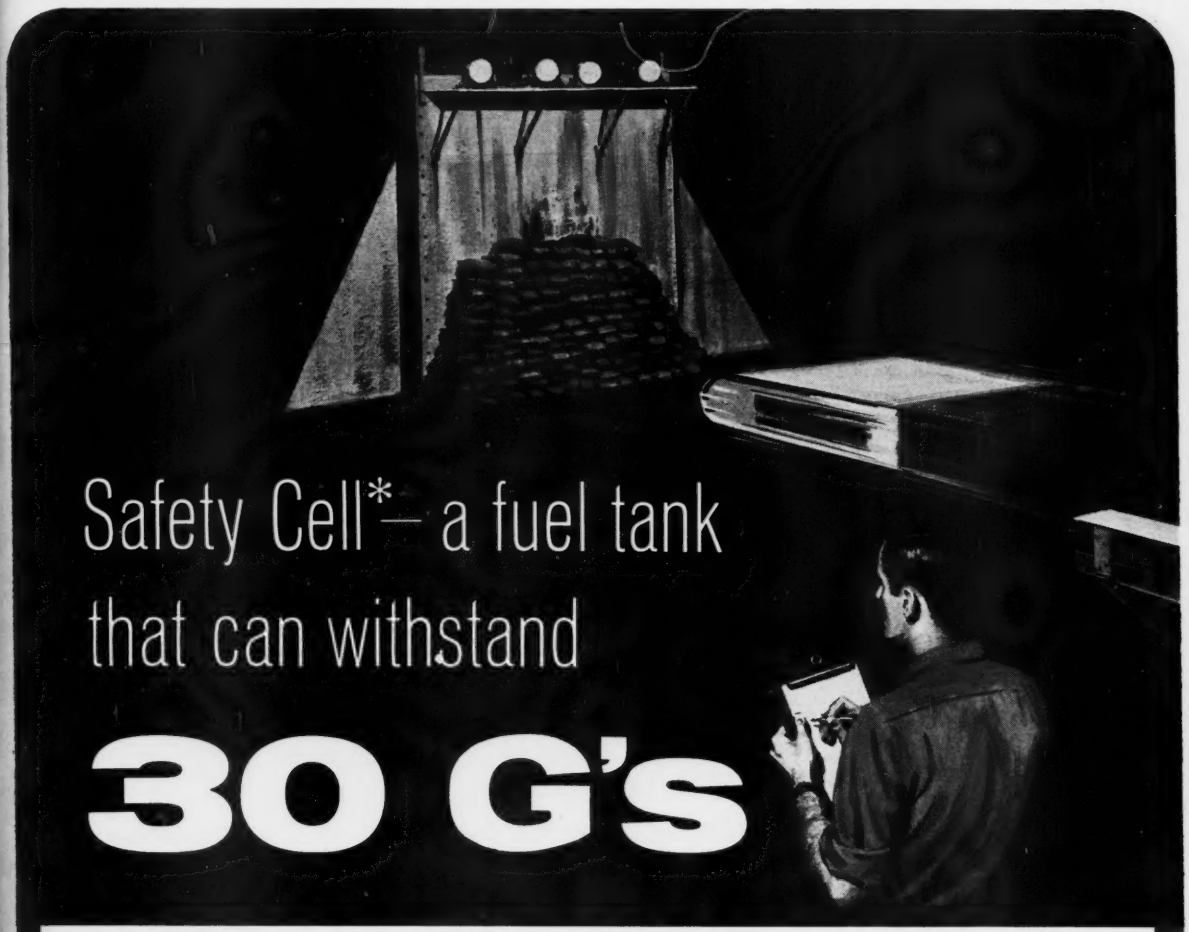

Safety Cell*—a fuel tank that can withstand 30 G's

THE PROBLEM: how to control aviation fuel during high-impact conditions so that instantaneous vaporized combustion can be prevented.

THE GOODYEAR ANSWER: Safety Cell, a high-strength, low-weight fuel tank made of super-tough rubberized fabric. Under exhaustive testing, in cooperation with the Federal Aviation Agency, these tanks have successfully withstood impacts exceeding 30 G's—maximum level of human tolerance. This means that the danger of vaporized combustion at impact is substantially reduced. Thus, the opportunity for survival is materially increased. A number of these tanks are already in use.

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On our cover

Well on its way to receiving full certification, Grumman Aircraft Engineering Corporation's prop-jet Gulfstream is pictured on a test program flight. The pressurized, high-performance transport was provisionally certified in March. Powered by two 2105 e.s.hp. Rolls-Royce Dart engines, it can carry up to 20 passengers and was designed for certification under CAR-4b and SR 422A governing turbine-powered transport aircraft. The Company is turning out the new planes at the rate of three a month and has begun assembly work on No. 19.

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"The prestige magazine of the Aerospace Industry"

AERO/SPACE ENGINEERING

VOLUME 18 / NUMBER 5 **May 1959**

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LETTERS to the Editor

A/SE Becomes a Curriculum

■ You are probably aware that the name of your magazine is becoming increasingly proper terminology to indicate combined interests in aeronautics and spatial technology. Certainly, at least, we are seeing the term "aero-space" used more and more as the engineering profession gains added depth.

In this regard, you will be interested to know that starting in 1959–60, the University of Arizona at Tucson will offer B.S., M.S., and Ph.D. degrees in Aero-Space Engineering. (A new curriculum of Aeronautics and Astronautics was instituted at the University last Fall—designed around a "common core" of 95 credit hours required of all engineering students, and 20 hours required by the University department.)

The Aero-Space Engineering curriculum prepares the student for entry into the established field of aeronautical engineering and/or the relatively new field of missile and space engineering. Because no precedent existed at the University regarding the field of Aero-Space Engineering, and because of the strong support of the new Head of Mechanical Engineering, Prof. H. D. Christensen, it is believed that this curriculum represents a bold step in better preparing the graduating student with the essential tools needed to cope with a rapidly changing field of engineering.

This new major at the University of Arizona, in addition to an up-to-date aeronautical engineering program, is supplemented by undergraduate courses in the basic principles of rocket flight, automatic control, and system analysis. In the graduate level, there is a continuation of the basic principles of rocket flight along with the fields of aeroelasticity, nonlinear oscillations, propulsion, stability and control, and preliminary design.

D. J. Alley
Assoc. Prof., Mech. Engrg.
University of Arizona

✦ ✦ ✦

Toward Better Reliability

■ The letter to the Editor in the January, 1959, issue of AERO/SPACE ENGINEERING by Institute of Aeronautical Sciences President William Littlewood regarding reliability, with an invitation to discuss broadly the problem at the basic level, prompts comment.

While some gains in the reliability of simple machines or systems may be made through organizational and procurement innovations within the existing state of science, there is a point in the trend of rising system complexity beyond which new and improved techniques and associated data inputs providing orders of magnitude improvements are required. As the needs increase for higher mission success probability, economy of means, and avoidance of lethal hazards, as in manned space vehicle systems, the importance of improving methodology grows. As the experience from which empirical data may be extracted diminishes numerically to the vanishing point, the need for new techniques becomes eminently apparent.

Several years ago the NACA took cognizance of this problem as evidenced by a study of the operational reliability of gas-turbine engines. The results of this study (recently released in an unclassified report) and those from kindred investigations in the communication and electronic industries provide important guideposts for improving reliability engineering in the future. My comments reflect what I think the steps of this development should comprise.

Reliability may be quantitatively expressed as the probability of avoiding failure. Denoting probability as P and reliability and failure as R and F, respectively,

$$P_R = 1 - P_F$$

As discussed by Ault and Garrett in the NACA report on reliability (and others), failures may be classified and denoted as: (1) Initial, P_{FI}; (2) Wearout, P_{FW}; and (3) Chance, P_{FC}. Then,

$$P_R = 1 - \Sigma(P_{FI} + P_{FW} + P_{FC})$$

from which we see that the quantitative treatment of reliability requires the evaluation of each class of failure with consideration for the variation of the failure rate with time. Initial failures occur at time = 0. Wearout failures occur with time dependency expressed by the well-known Gaussian distribution. Chance failures have constant rate with time which is expressed by a Poisson function. An understanding of the failure mechanism in a microscopic sense leads to failure classification. The origins of failure mechanisms reside in the internal physical characteristics of the system, the external environment, and the interaction between human factors and the machine system. Knowledge of failure origins is an aid to understanding mechanisms and establishing time to failure relationships. The state of science permits treating some simple systems; however, additional work at the fundamental level is needed to develop classification and analytical technique for the evaluation of reliability probabilities in relation to the time elapsed after start of service of complex systems. Of particular importance is the development of failure probabilities in a system yet to be put in service.

The payoffs from a fundamental understanding of reliability will include the following:

(1) Ability to plan economic operation of a transport or weapon system.

(2) Ability to assess the probability of mission success.

(3) Ability to predict lethal-type hazards in systems operations.

(4) Design, operational, inspection, and maintenance improvements needed to increase operational reliability by quantitatively specified increments.

(5) Identification of voids in the knowledge to be investigated in future research and development.

Consideration of the reliability of manned space vehicle systems serves to dramatize the challenge of the problem. Sending men into space has many purposes, not the least of which is to demonstrate the ability of Western science to make technical progress in the interest of humanity. Sending a man into space without knowledge of his chances of safe return hardly belongs in this crusade.

Steps by which reliability engineering can be objectively improved include the following:

(1) Formation of Research and Development teams comprised of operators, system design managers, and system component vendors for the purpose of assembly, analysis, and evaluation of reliability data on existing systems.

(2) Study of systems reliability in Research and Development teams of increasingly complex systems and the generalization of the results.

(3) Development of reliability criteria for systems yet to be put in operation.

(4) Provision—in future procurement contracts of weapons or transport systems—for the evaluation of the reliability of the procured system on the basis of identified failure mechanisms and historical failure statistics of valid samples.

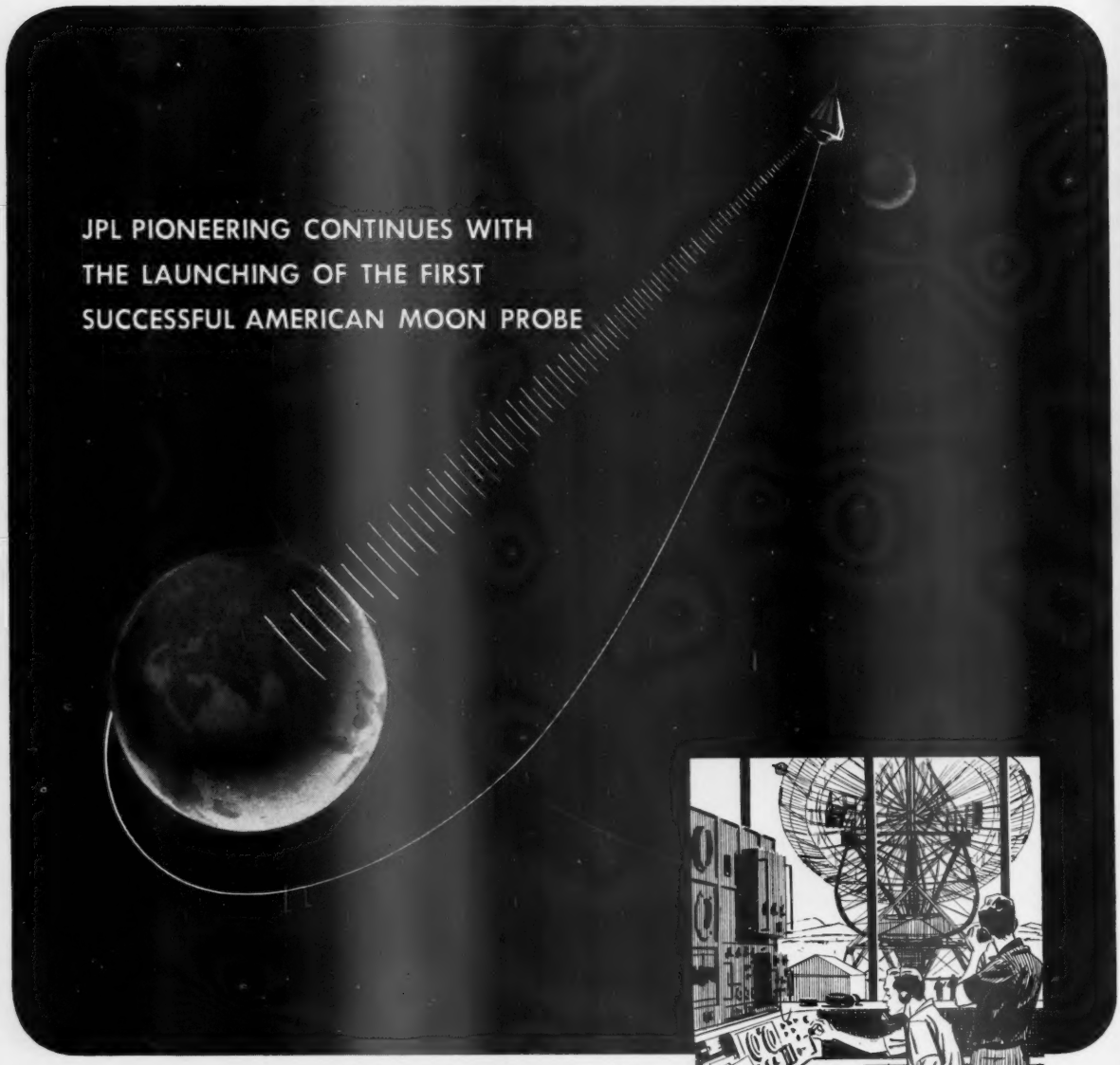
The writer would be pleased to learn of the reaction of others to Mr. Littlewood's letter.

The comments herein expressed are the opinions of the writer and do not necessarily represent the position of Lockheed in regard to reliability.

Lewis A. Rodert, FIAS
Research Assistant
Lockheed Aircraft Corp.

The Editors welcome letters from readers, although none can be acknowledged. All must be signed, but identities will be withheld on request.

NOTABLE ACHIEVEMENTS AT JPL...



The JPL tracking station at Goldstone in the Mojave Desert in California

Early on March 3, 1959, Pioneer IV space probe was launched from Cape Canaveral, Florida to become America's first deep-space vehicle capable of escaping the earth's gravitational pull. On its way past the moon and out into orbit around the sun, this new man-made planet sent back valuable information on the radiations present in space. Several Free World tracking stations clearly received its transmitted signal and helped to establish its distance, velocity, and direction.

Under the sponsorship of the National Aeronautics and Space Administration, JPL designed and built not only the conical payload of Pioneer IV but also the three upper stages of the Juno II launching vehicle, containing new high-performance JPL solid propellant rockets.

Over a year ago the same JPL team, in cooperation with ABMA, gave America its first earth satellite, Explorer I, using a similarly reliable vehicle – the Jupiter C.

Now, more advanced space vehicle programs are under way at JPL — programs which include development of guidance and propulsion systems for accurate maneuvers many million miles from the earth.

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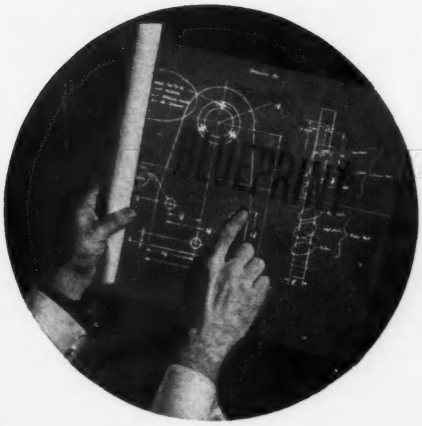

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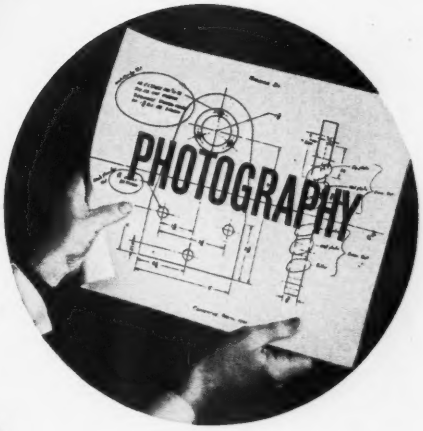

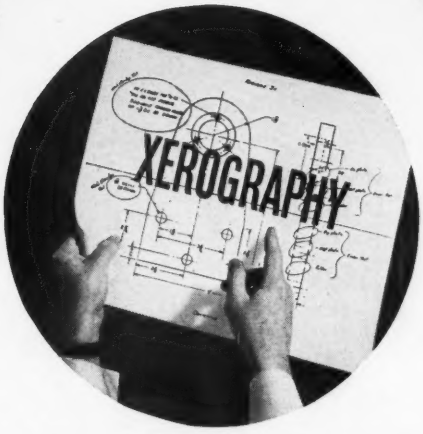

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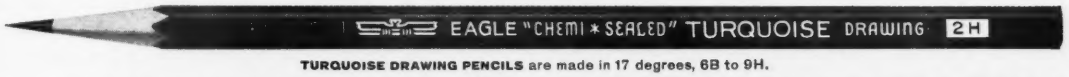

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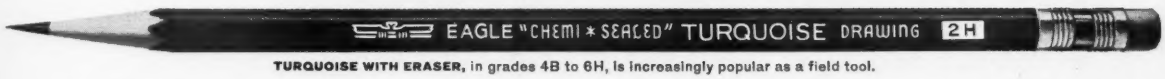

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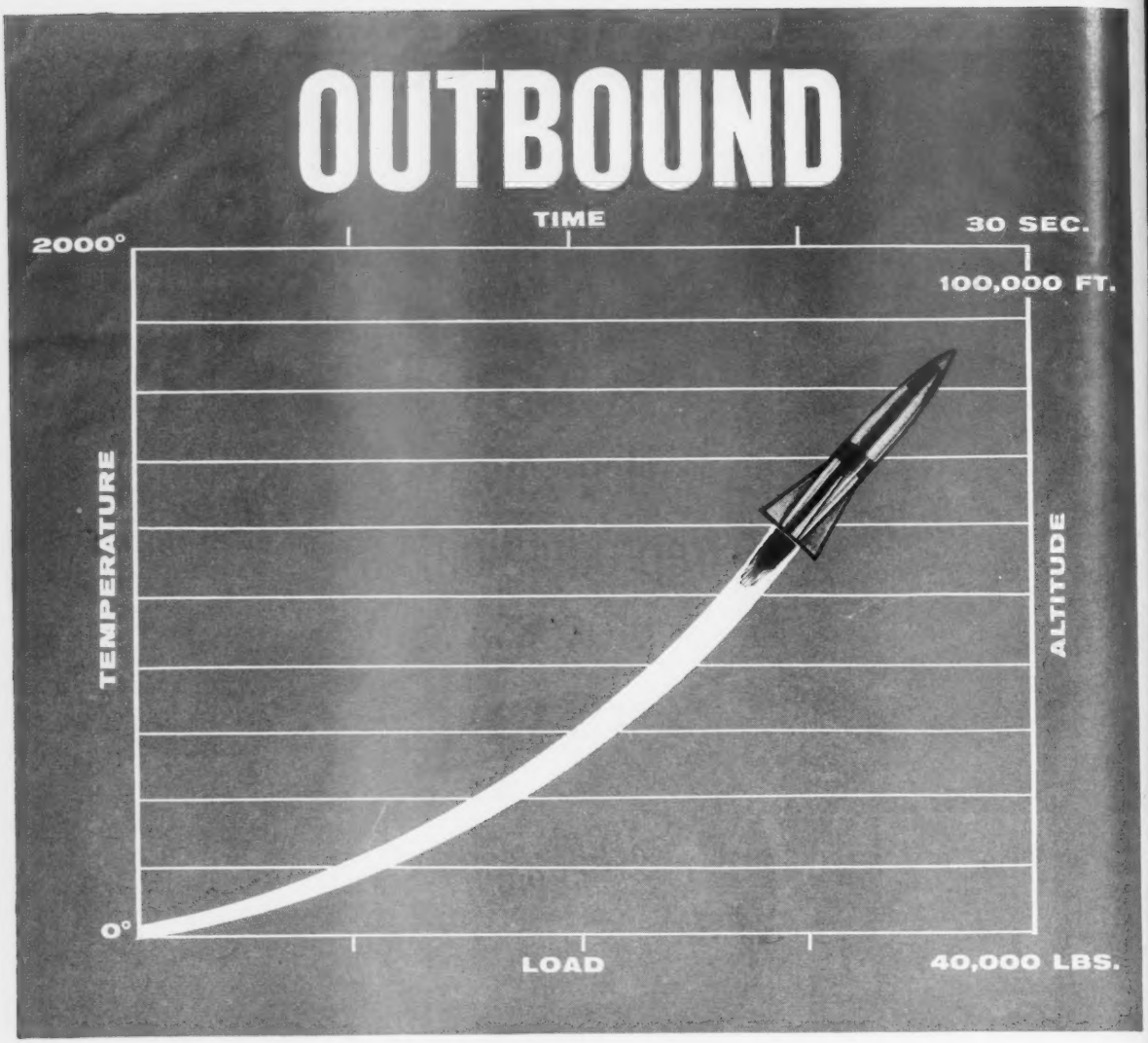

Second by second, higher-order performance is required of today's missile design—even as temperatures and loads are on the increase geometrically.

These are familiar problems to Shafer Engineers who have pioneered in the research and development of bearings to meet these higher-order requirements on many of today's outbound missiles. For example, Shafer research on the coefficient of expansion of materials—and the many other physical properties at elevated temperatures—establishes Shafer as a leader in high-temperature bearing design.

The famous exclusive design features that have made Shafer first choice for the toughest bearing applications in the airframe industry—greater capacity for its envelope dimensions and weight... integral self-alignment with full capacity...greater resistance to shock loadings and vibrations—may provide the answer to your missile control system bearing problems.

The time for you to draw on Shafer experience is now—before you lay in bearings on your latest missile design. And remember, too, Shafer advantages can provide important answers to bearing problems on ground support equipment as well as the "birds" themselves. Before you lay bearings in—call on Shafer experience.

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the **Green Sheet**

IAS BULLETINS AND LATE NEWS . . .

May, 1959

NSM ADDENDUM: An additional technical session, making a total of 18, has been added to the program of the National Summer Meeting. The session, IGY Results, cosponsored by The National Academy of Sciences, will be held on the evening of June 19. It will be chairmanned by Roger Reville, Director, University of California at La Jolla. Details of the meeting and program are on page 13.

IAS PRESIDENT WILLIAM LITTLEWOOD has been appointed Chairman of the NASA's Research Advisory Committee on Aircraft Operating Problems.

DURAND CENTENNIAL CONFERENCE on the problems on hypersonic and space flight will be held at Stanford University on August 5-7, in honor of the 100th anniversary of the birth of William Frederick Durand HFIAS, pioneer aeronautical engineer. Speakers include: H. Julian Allen, Ames Research Center, NASA; Luigi Broglio, University of Rome, Italy; Johannes M. Burgers, University of Maryland; Francis Clauser, The Johns Hopkins University; Hugh L. Dryden, NASA; Wilfred H. Dukes, Bell Aircraft Corp.; Antonio Ferri, Polytechnic Institute of Brooklyn; Richard R. Heldenfels, Langley Research Center, NASA; Wolfgang B. Klemperer, Douglas Aircraft Co., Inc.; Leslie S. G. Kovasznay, The Johns Hopkins University; Hans W. Liepmann, California Institute of Technology; Gordon N. Patterson, University of Toronto, Canada; Sir Geoffrey Taylor, Cambridge University, England; R. H. Thielemann, Deutsche Versuchsanstalt fur Luftfahrt E. V., Germany, and others. The conference is sponsored by IAS, AFOSR, ONR, OOR, and NSF.

GROWTH NOTE: The Institute, sometime during the last month, passed the 15,000 graded member mark (this figure excludes 4,600 student members) and the monthly print order for Aero/Space Engineering has climbed to 20,000 copies.

"INVESTIGATION OF SPACE" is the theme of the 1959 National Telemetering Conference coming up May 25-27. This theme will be followed through with papers on advanced telemetry systems for space investigation, new calibration techniques, transistorization, new techniques in ground stations and data processing, and biomedical aspects of space telemetering.

WHAT'S IN THE NAME AERO/SPACE ENGINEERING? Our "Letters" page in this issue has an answer, and interesting data on a new curriculum.

INTERNATIONAL, NATIONAL & JOINT MEETINGS CALENDAR

May 4-6 IRE National Aeronautic Electronic Meeting, Dayton Biltmore Hotel, Dayton, Ohio. IAS participating.

May 25-27 National Telemetering Conference, Cosmopolitan Hotel, Denver.

Green Sheet (Con't.)

June 11-13	Heat Transfer and Fluid Mechanics Institute, University of California, Los Angeles. IAS participating.
June 16-19	IAS National Summer Meeting, Ambassador Hotel, Los Angeles.
Aug. 24-26	National Specialists Meeting Symposium on Anti-Submarine Warfare (Classified), San Diego, California.
Sept. 9-11	Midwestern Conference on Fluid and Solid Mechanics, University of Texas. Cosponsored by IAS, AFOSR, ONR, NSF, and eleven technical societies. For more information, contact Prof. M. J. Thompson, Chairman, Department of Aeronautical Engineering, University of Texas, Austin 12, Texas.
Sept. 16-17	Western Regional Meeting on Frontiers of Science and Engineering, Los Angeles, California.
Oct. 5-7	Seventh Anglo-American Conference--Technical Sessions--Hotel Astor, New York, New York.
Nov. 2-4	Midwestern Meeting on New Frontiers in Aviation, Hotel Lassen, Wichita, Kansas.
Nov. 17-18	National Air Transportation Meeting, San Francisco, California.
Dec. 17	Wright Brothers Lecture, Washington, D. C.

IAS SECTION MEETINGS CALENDAR

May 12	Los Angeles: Specialist Meeting, IAS Building, 8 p.m. Minta Martin Lecture "Rocket Propulsion for Space Flight" by George P. Sutton.
May 12	Washington: Dinner Meeting (Social 6, dinner 6:45, meeting 8 p.m.), International Room, Occidental Restaurant, Washington (D.C.) "FAA's Immediate and Future Plans for National Aviation" by Elwood R. Quesada.
May 13	Niagara Frontier: Technical Meeting, 8:30 p.m. Cornell Aeronautical Laboratory. "Human Factors Research in Air Traffic Control" by Dr. H. Richard Van Saun, FAA.
May 14	New York: Flight demonstration, tour, dinner, and meeting (6, 6:45, 7:30, 8:30 p.m.), Sikorsky Aircraft Division, Stratford, Conn. Talk by Igor I. Sikorsky.
May 19	Boston: Annual Dinner Meeting, Thompson Club, Nahant, Mass., 6 p.m. Panel discussion on "The Aeronautical Engineer."
May 19	Dayton-Cincinnati: Dinner Meeting, Embers Supper Club, Fairborn, Ohio. "Recent Developments in Manned Space Flight" by Colonel John P. Stapp, USAF.
May 19	Wichita: Dinner Meeting, Innes Restaurant, 6:30 p.m. "The Development of the Polaris IRBM" by Stanley W. Burriss.
May 21	Los Angeles: Dinner Meeting (Social 6, dinner 7, meeting 8 p.m.) IAS Building, "This Is Your Air Force Academy" by Col. Paul H. Dane, USAF.
May 22	Great Salt Lake: Dinner Meeting (Social 6:30, dinner 7:30, meeting 8:20 p.m.), Hill Air Force Base, Utah. "Ram-Jets in the Space Age" by Roy E. Marquardt.

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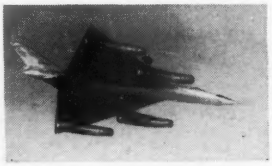

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XUM

COMMAND DESTRUCT

The flight testing of second generation missiles—more versatile and powerful than their predecessors—requires a device for sure termination of any missile flight that might endanger the test range or surrounding area.

Ramo-Wooldridge engineers, under a United States Army Signal Corps contract, have successfully developed and delivered the first sub-miniature, completely transistorized radio "command destruct" receivers.

Specifically designed for missile flight safety operations, the receiver (AN/DRW-11) can actuate safety mechanisms or destruct devices. It has three command channels, each of which actuates a control relay.

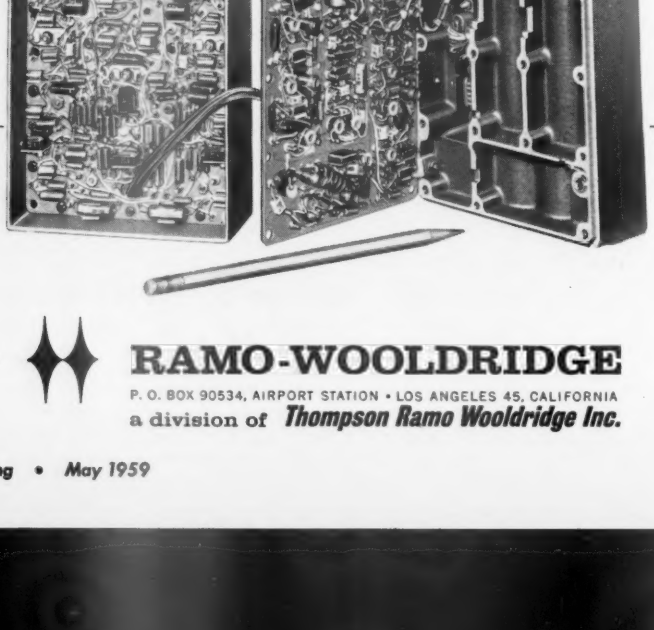
The "command destruct" receiver accepts frequency modulated signals in the UHF radio command control band. It is designed to operate with closer radio frequency and command frequency channel spacing than has been used to date, thus making possible more efficient use of the available radio spectrum.

Compact and rugged, the radio receiver's modular construction permits rapid and complete accessibility to all components. One module houses the basic receiver. The second module contains the three command channels and relays. This integrated package occupies 115 cubic inches, and weighs 4 pounds. The receiver requires no pressurization and operates reliably under the adverse environmental conditions encountered in missile flight testing.

Engineers and scientists interested in being associated with some of the nation's most advanced research and development programs are invited to acquaint themselves with current opportunities at Ramo-Wooldridge. The areas of activity listed below are those in which R-W is now engaged and in which openings exist.

Missile electronics systems
Advanced radio and wireline communications
Information processing systems
Electronic language translation
Anti-submarine warfare
Air navigation and traffic control
Analog and digital computers
Infrared systems
Electronic reconnaissance and countermeasures
Basic and applied physical research

For a copy of our brochure, *An Introduction to Ramo-Wooldridge,* or other additional information write to Mr. Donald L. Pyke.



RAMO-WOOLDRIDGE

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IAS News

. . . a record of people and events of interest to Institute Members

Missile Range Field Trip, 17 Technical Sessions Set for National Summer Meeting in Los Angeles

4-Day Program to Start June 16; Secretary of the Air Force James H. Douglas Will Speak at Banquet

SEVENTEEN TECHNICAL sessions and the presentation of upwards of 65 papers have been scheduled for the Institute's 4-day National Summer Meeting at the Ambassador Hotel in Los Angeles, beginning on June 16. A field trip will climax the meeting on the 19th.

The program, designed to satisfy a variety of interests in the aero/space sciences, has been planned by a special committee of the Los Angeles IAS Section headed by John R. McMaster as General Chairman. Malcolm J. Abzug is Chairman of the host section.

Six of the 17 sessions are classified and will be cosponsored by the USAF's Air Research and Development Command Office in Los Angeles. The field trip, to the Naval Missile Center at Point Mugu, also is classified. Those attending will see a display of United States guided missiles.

James H. Douglas, Secretary of the Air Force, will address the meeting banquet on the evening of the 18th. IAS President William Littlewood will be toastmaster.

Sessions, and their Chairmen, are as follows:

Tuesday, June 16

Structures: E. H. Spaulding, Chief Technical Engineer, California Division, Lockheed Aircraft Corp. **Space Flight:** Krafft A. Ehricke, Program Director, Convair Astronautics. **Space Propulsion and Space Recovery Techniques:** Welko Gasich, Director, Weapon System Development Engineering, Northrop Corp. **Structural Design for Hypervelocity Vehicles:** F. R. Shanley, Professor of Engineering, University of California at Los Angeles. **Development Projects (Classified):** L. Eugene Root, General Manager and Vice-President, Missiles and Space Division, Lockheed Aircraft Corp.

Wednesday, June 17

Hypersonic Aerodynamics and Real Gas Effects: Clark B. Millikan, Director, Guggenheim Aeronautical Laboratory, California Institute of Technology. **Advanced Detection Techniques (Classified):** Sidney Passman, Physical Scientist, The RAND Corp. **Aerodynamics (Classified):** Harrison A. Storms, Chief Engineer, Los Angeles Division, North American Aviation, Inc. **Electronic Systems:** Michael T. Gannon, Chief Engineer, Missile Guidance, Pacific Division, Bendix Aviation Corp. **Education:** Lt. Col. James H. Polve, USAF, Associate Professor of Aerodynamics, U.S. Air Force Academy. (Cosponsored by ASEE.) **Strategic Air Command Briefing (Classified):** Major Gen. J. V. Edmundson, Director of Operations, Headquarters, SAC.

L.A. Section Chairman Abzug

General Chairman McMaster

Thursday, June 18

Propulsion: W. Duncan Rannie, Professor of Jet Propulsion, California Institute of Technology. **Phenomena of Transonic and Supersonic Flows:** Harold Luskin, Assistant Chief of Aerodynamics, Santa Monica Division, Douglas Aircraft Co., Inc. **Supersonic Transports:** Harold F. Kleckner, Advanced Design Engineer, Santa Monica Division, Douglas Aircraft Co., Inc. **Propulsion (Classified):** D. C. Berkey, Manager, Jet Engine Department, General Electric Company. **Vehicle Development Testing (Classified):** W. W. Withee, Assistant Chief Engineer (Test), Convair Astronautics. **VTOL Aircraft:** N. E. Nelson, Chief Engineer, Doak Aircraft Co., Inc.

Luncheon speakers will be: *On Tuesday*, Vice-Adm. W. G. Cooper, Commander, Antisubmarine Defense Force, U.S. Atlantic Fleet. *On Wednesday*, Homer J. Stewart, Director of Programs and Planning, NASA. *On Thursday*, Peter G. Masefield, Managing Director, Bristol Aircraft Ltd. All luncheons will take place in the Ambassador Hotel's Cocoanut Grove, as will the banquet. Luncheon toastmasters, in the order as given above, will be Rear Adm.

(*Continued on page 19*)

new symbol
for
systems

In five years of operation, Consolidated Systems has climbed from less than one-quarter million to over eight million dollars in custom-engineered systems for dynamic and static testing, chemical analysis, industrial control, and high-speed analog and digital data processing. This unprecedented growth in specialized systems (including missile ground support and cryogenics) is proof of quality – of performance – and of customer satisfaction. Over 500 systems have been designed, manufactured, and installed. These are *operating* systems producing data where time is critical and performance is paramount. Read about them in Bulletin CEC 1304-X50.

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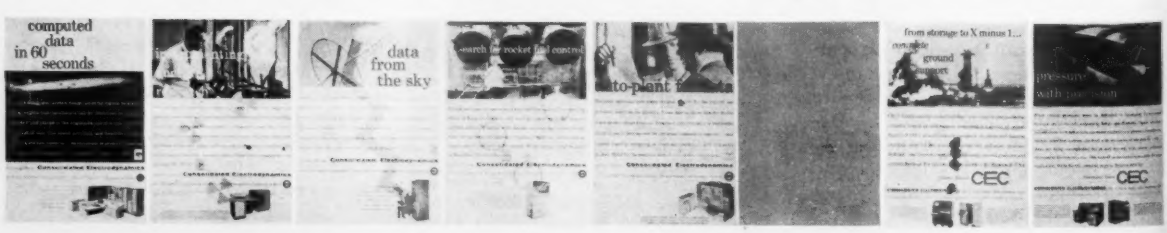


IAS Flight Test Engineering Fellowship for '59 Goes to Fox Conner, of Lockheed

Award Provides $7,300 for Study at Princeton University

A Lockheed Aircraft Corporation engineer is the Institute of the Aeronautical Sciences' Flight Test Engineering Fellow for 1959.

The successful candidate for the IAS Flight Test Engineering Fellowship is Fox Conner. His duties at Lockheed have included testing the F-104 Starfighter series.

The award totals $7,300 and is one of the most significant fellowships available in the aero/space engineering field. It provides for tuition and stipend covering 2 years of graduate study at Princeton University. Mr. Conner, granted a leave of absence by Lockheed, will enroll for the Fall semester.

Speaking on behalf of the Board of Award, of which he is a member, IAS Director S. Paul Johnston noted "the exceptionally high caliber of applicants whose credentials were before the Board when study of qualifications began." He said, "Many possessed qualifications and scholastic records worthy of serious consideration by the nation's top graduate schools." (An indication of this lies in the fact that Princeton offered fellowships of its own to several of the runners-up.) Other members of the Board are Hugh L. Dryden, Deputy Administrator, NASA, and Courtland D. Perkins, Chairman of Princeton's Aeronautica Engineering Department.

Mr. Conner, at 30, has over 8 years' engineering experience to take with him to Princeton as a background to his studies, as well as B.S. and M.S. degrees in aeronautical engineering. An M.I.T. graduate, receiving his B.S. in 1950, Mr. Conner spent 5 years with Republic Aviation Corporation, Farmingdale, L.I., N.Y., in all major phases of flight test engineering.

While at Republic, Mr. Conner worked primarily on testing the F-84, with emphasis on power-plant operation, stability, control, and general performance characteristics. In 1955, he became associated with Lockheed at its Palmdale, Calif., facilities and was assigned to test the F-104 series. His responsibilities were broadened to include project and analysis engineering.

Even though working full time, Mr. Conner went on with his studies, matriculating at the University of Southern California and completing his work last February. Married and a resident of Palmdale, he is the son of Mr. and Mrs. Fox Brandreth Conner, of Somerstown Road, Ossining, N.Y.

The successful candidate for the 1959 IAS Flight Test Engineering Fellowship, Fox Conner, of Lockheed Aircraft Corporation, is pictured at the cockpit of Lockheed's F-104 Starfighter.

The idea of an annual IAS fellowship in Flight Test Engineering was conceived in 1954 to give substantial financial assistance to young, promising aeronautical engineers (both graduate students and practicing professionals) to build "a solid foundation of advanced technical training in the science of test flight."

Since 1954, six awards have been given, including this year's. Three winners have completed studies and returned to industry, and two are winding up their first and second years of study.

The curriculum of each winner is planned by the Princeton faculty to encompass the full potential of the individual. However, programs completed by prior winners have included courses in Advanced Aerodynamics, Vibrational Theory, Design Practice, Aeroelasticity, and a Seminar in Instrumentation.

Application forms are obtained yearly from IAS National Headquarters in New York in time to meet a closing date of March 1.

Previous IAS Flight Test Engineering Fellows

1954—David G. Powell, now Research Engineer, California Division, Lockheed Aircraft Corp.

1955—Warren G. North, now with Missile Design Panel, Lewis Research Center, NASA.

1955—William B. Brown, now assigned to a highly classified project in The Martin Co.

1957—Franklin F. Eckhart, former U.S. Navy Pilot, now in his second year of study at Princeton.

1958—Henry B. Grudberg, former U.S. Army Helicopter Pilot, now in his first year of study at Princeton.

what is entropy?

Heat lost except at absolute zero?

A measure of disorder?

A statistical probability of state?

The gradient of a scalar?

Macrocosmic phenomenon or microcosmic, too?

The fundamental concept of entropy is involved in many phases of our technology. Hence we have a fundamental need to know everything we can about its significance. This knowledge is critical to our work of energy conversion.

Thus we probe and inquire, search without wearying – call upon the talents of General Motors Corporation, its Divisions, and other individuals and organizations – for a complete appreciation of all phases of scientific phenomena. By applying this systems engineering concept to new research projects, we increase the effectiveness with which we accomplish our mission – exploring the needs of advanced propulsion and weapons systems.

Energy conversion is our business

ALLISON

Division of General Motors, Indianapolis, Indiana

Grover Loening, IAS Founder, Benefactor, and Fellow Delivers Inaugural Lecture at M.I.T. Honoring Lester D. Gardner

TAKING AS his subject "Lessons From the History of Flight," Grover Loening, Fellow, Benefactor, and a Founder of the Institute of the Aeronautical Sciences, and one of the distinguished figures in American aviation, delivered the first Lester D. Gardner Lecture on April 10 in the Department of Aeronautics and Astronautics at M.I.T.

The lectures are made possible by a bequest of the late Mr. Gardner, who also was among the founders of the IAS, and who for many years was its chief executive. A graduate of M.I.T. '98, the tireless "Major" was instrumental in his later years in creating the Hunsaker Professorship in Aeronautical Engineering at M.I.T. He maintained an active interest in aviation until his death in November, 1956. He was an air officer in World War I.

In his lecture, Mr. Loening drew upon his half-century of experience in many segments of the aviation industry and delved into history to present some suggestions for guidance in the complex problems facing the aero/space engineer-scientists, and manufacturers, of today.

After citing advances which have brought air transportation to its current state, Mr. Loening observed that we still need higher performance—"but with better traffic control and with reduction of noise levels and of space needed for landing and take-off." Pointing to current great costs of aircraft development, but also to its vital nature, he warned that "we must seek every effective way to make our progress both cheaper and quicker."

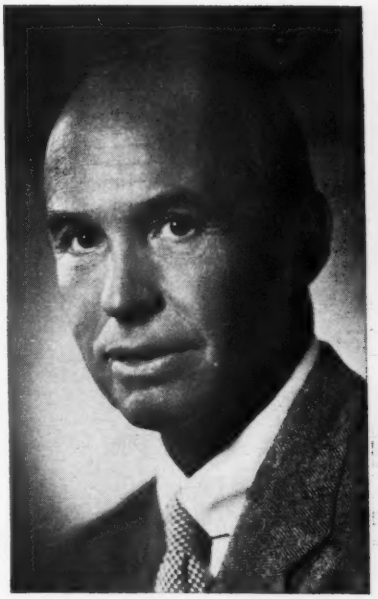
Mr. Loening was the first aeronautical engineer employed by Orville Wright. In addition to his interest in founding the Institute of the Aeronautical Sciences, he was among the founders of Pan American Airways, of Grumman Aircraft Engineering Corp., and of other professional and industrial enterprises.

He completed studies at Columbia University in 1910, where his thesis—one of the first on aeronautics in an American university—was monitored by Prof. Richard C. Maclaurin, then Head of the Physics Department. Dr. Maclaurin was soon to become President of M.I.T. and to establish there the first course in aeronautical engineering in this country.

After his service with Orville Wright, Mr. Loening became the first aeronautical engineer employed by the Army. In 1917 he formed his own company and built a series of successful airplanes based on new engineering concepts, such as strut-based monoplanes, a monoplane flying boat, and the widely used Loening amphibian; he also pioneered retractable landing gears.

Mr. Loening was the first president of the Aeronautical Chamber of Commerce; during World War II he served as Aircraft Advisor to the War Production Board; in 1948 he was Advisor for Research and Development of the President's Air Policy Commission; and from 1945 to 1958 he was a consultant to the National Advisory Committee for Aeronautics. Today he is a Director of the Flight Safety Foundation, New York Airways, and Fairchild Engine and Airplane Co.; a member of the Advisory Board of the National Air Museum; and consultant to the Navy and Air Force.

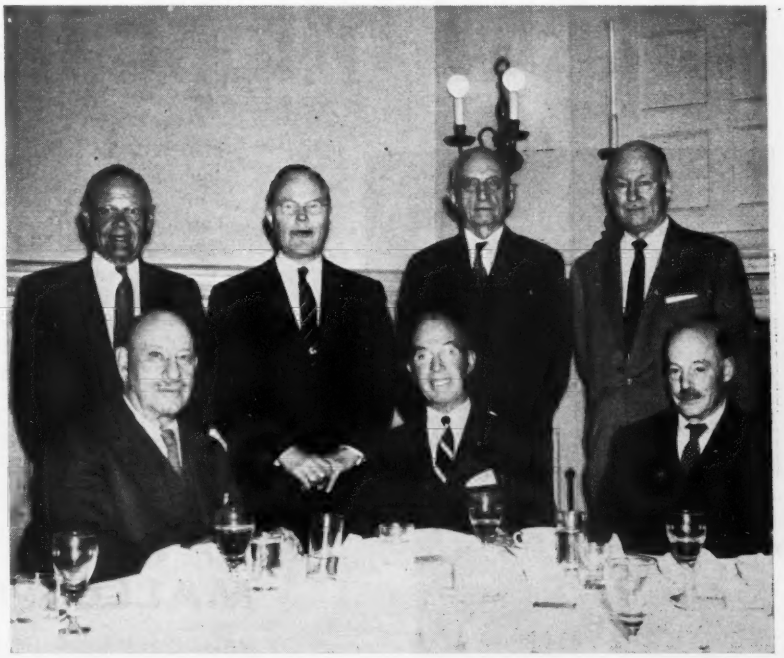
Mr. Loening holds the Collier Trophy (1921), the Legion of Merit (1948), the Egleston Medal (1950), the Wright Brothers Trophy (1952), and the Air Force Medal (1955).



Grover Loening

SOME OF THOSE WHO MADE AERONAUTICAL HISTORY

Following the presentation of the first Lester D. Gardner Historical Lecture by Grover Loening at M.I.T. on April 10th 1959, Dr. Jerome Hunsaker gave a small dinner at Boston's Union Club at which a notable group of men who had contributed to aeronautical history were present. Seated *(left to right)* are Rear Adm. Luis de Florez, USNR (Ret.); Grover Loening; Dr. Jerome C. Hunsaker; standing *(left to right)* are Elmer A. Sperry, Jr.; E. E. Aldrin; Comdr. Frederick G. Coburn, USN (Ret.); and Vice Adm. C. E. Rosendahl, USN (Ret.).

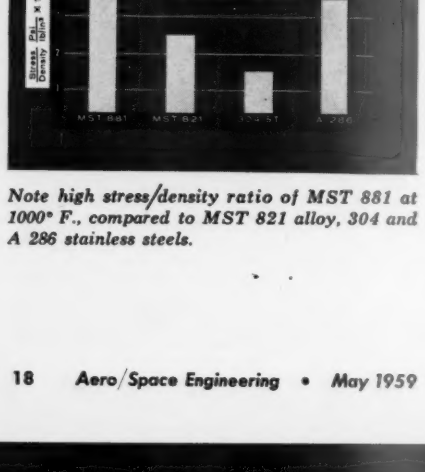


PROGRESS REPORT

New Mallory-Sharon 1100° Titanium Alloy

MST 881

BREAKS THE HEAT BARRIER


COMPARISON OF MST 881 WITH CONVENTIONAL HIGH TEMPERATURE MATERIALS
Stress-Density Ratio For 100 hr. Rupture at 1000°F
Stress, Psi / Density, lb/in³ x 10⁻³
MST 881
MST 821
304 ST
A 286

Note high stress/density ratio of MST 881 at 1000° F., compared to MST 821 alloy, 304 and A 286 stainless steels.

MST 881, the new high temperature titanium alloy recently announced by Mallory-Sharon, has been successfully forged on a production basis... meeting aircraft industry specifications. Leading manufacturers are now testing MST 881 for use in compressor shafts, wheels and blades in Mach 3 jet engines ... where prolonged high temperatures will be encountered.

Studies are also being carried out on application of MST 881 in the landing apparatus of manned skip-glide vehicles, in high temperature gears, machine gun poppet valves, and steam turbines operating at 1000° F.

MST 881 provides excellent long term strength characteristics at temperatures of 1100° F., and, for short periods, at temperatures as high as 1600° F. This new material offers promising application possibilities for missile, engine and airframe producers. Write today for Technical Data Sheet on MST 881.

MALLORY SHARON

MALLORY-SHARON METALS CORPORATION • NILES, OHIO

National Summer Meeting

(*Continued from page 13*)

J. P. Monroe, USN, Commander, Pacific Missile Range; Louis G. Dunn, President, Space Technology Laboratories, Inc.; and IAS Vice-President C. L. Johnson, Vice-President, Advanced Development Projects, Lockheed Aircraft Corp.

Admiral Monroe also will be host to IAS participants in the Friday field trip to the Pacific Missile Range.

Summer Meeting Committee planners have been R. E. Bateman, Boeing Aircraft Co.; J. W. Ellinwood and Kenneth Nicholson, of Douglas; Stanley Mikulka, of G-E; Alexander Satin, of J. H. Pomeroy & Co.; Edward Marriott, of Hughes Aircraft; C. R. Cantrell, J. S. Clauss, D. L. Kelly, and E. B. MacCuish, of Lockheed; John Allen and P. H. Anderson, of North American; Lee Begin and William Dedon, of Northrop; Ben Cagle and Frank Friedlaender, of Southern California Cooperative Wind Tunnel; Col. Guy M. Townsend and Major Frank G. Lester, USAF; Allen Brown and Ronald Toms, of Wiancko Engineering.

Del Mar Becomes Corporate Member

Del Mar Engineering Laboratories has sold 26,000 targets to the military air services of the United States and its NATO allies in less than 5 years. Del Mar facilities are located at the Los Angeles International Airport and include over 50,000 sq.ft. of production area. Further expansion is planned to fulfill increased electronic production demands. The company also maintains three field service and military sales offices located in the U.S. and Canada.

Del Mar "pioneered" the lightweight, high-speed "RADOP" tow target system. The RADOP target, which is launched and recovered in flight, has since been used at supersonic speeds and has been destroyed in both day and night missile firing exercises.

Necrology

Paul W. Litchfield

Paul Weeks Litchfield (A) died March 18 at the age of 83. He had retired last October as Board Chairman and chief executive officer of Goodyear Tire and Rubber Co. after 61 years in the industry. At the time of his death, he was Honorary Chairman of the Board.

Mr. Litchfield, dean of the rubber industry in this country for many years, was a pioneer builder in the field of dirigibles. A record of his many achievements blends into the history of the Goodyear Tire and Rubber Co. He joined the company on

Paul W. Litchfield

July 15, 1900, when it was 2 years old and he was almost 25. The connection lasted more than 50 years.

He started as superintendent of all production, development, and engineering of the small Akron firm which turned out bicycle tires and sundries, pneumatic carriage tires, etc. But Mr. Litchfield was factory manager by 1911, and a vice-president 4 years later. It was not until 1926 that he was named President of Goodyear, and he became Chairman of the Board as well in 1930. He relinquished the presidency in 1940.

Aeronautics attracted him in 1910. He imported equipment to coat balloon fabric with rubber and that same year placed on the market the first pneumatic tires for airplanes. This program expanded over more than 40 years to cover countless aircraft, balloons, and dirigibles during two wars and two peacetime decades.

Mr. Litchfield was graduated in 1896 from the Massachusetts Institute of Technology.

Paul B. Woyak, Jr.

The Institute has just been informed of the death of Lt. Paul B. Woyak, Jr., USNR (A), on July 10, 1958.

Lieutenant Woyak was a pilot with the VF-23 Squadron. He was 25 years of age and a graduate of the Cal-Aero Technical Institute.

IAS *News* — *News of Members*

Ira H. Abbott (F) has been appointed Deputy Director of Aeronautical and Space Research, NASA. He will continue to serve as Assistant Director of Research (Aerodynamics & Flight Mechanics), NASA.

Russell D. Archibald (M) has joined Hamilton Standard, division of United Aircraft Corp., as Project Engineer in the environmental controls group. He had been serving, with the rank of captain (USAF), at WADC as Project Engineer.

Ralph L. Bayless (AF), formerly Chief Engineer of the San Diego Division of Convair, has been appointed Director of Engineering for Convair.

Capt. Paul J. Burr, USN (Ret.) (AF), has become associated with Flight Support Inc., subsidiary of Pacific Airmotive Corp., of Metuchen, N.J., as Vice-President—Products and Planning. Before his recent retirement, Captain Burr was Director, Maintenance Division, BuAer.

Daniel B. Callaway (M), formerly Chief Engineer, Sound Control Department, The Koppers Co., has joined Industrial Acoustics Co., Inc., of New York, as Supervisor of West Coast activities. He will also provide western regional engineering services for IAC Noise Control Products.

William A. Chisholm (M), formerly Liaison Engineer with Canadair Limited, has been made Assistant Secretary of the Canadian Aeronautical Institute, Ottawa.

Arch T. Colwell (F) has been named to the newly created position of Vice-President—Engineering, Research, & Development at the corporate level of Thompson Ramo Wooldridge Inc. Mr. Colwell was formerly Vice-President of Thompson Products, Inc., and a member of the Board of Directors.

Phillips Eastman, Jr. (M), has been promoted to Vice-President—Administration of Hallamore Electronics Co., Anaheim, Calif. He was formerly Manager of their Denver branch.

James W. Flournoy (M) has been named Assistant Project Engineer by Lockheed Aircraft Corp.'s Georgia Division. He was formerly a Design Group Engineer.

William W. Fox (A), formerly Assistant Chief Engineer, has been promoted to

(*Continued on page 108*)

Capt. Paul J. Burr, USN (Ret.)

Progress in Space Technology

How General Electric delivered first U.S. operational re-entry vehicle

General Electric Missile and Space Vehicle Department helped USAF Ballistic Missile Division solve re-entry problem . . . speed Thor operational readiness.

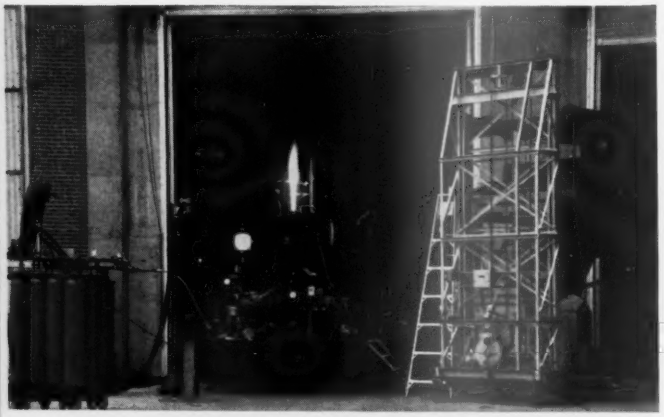
CAPABILITIES DEVELOPED RAPIDLY—Early in 1955, General Electric's Missile and Space Vehicle Department began research and development work on the vitally important re-entry phase of the USAF ballistic missile program. A skilled core of G-E scientists with hypersonic and missile technology experience were pulled together from all parts of the Company. Special research tools were developed and put into use at MSVD's new Aerosciences Laboratory. Advanced shock tunnels reproduced high Mach air flows—10,000 to 25,000° F plasma jets simulated extreme re-entry heats. With such new tools, G.E. gained vital knowledge of the re-entry environment.

FLIGHT TEST PROVED DESIGN—MSVD engineers were convinced that the heat-sink type re-entry vehicle offered the best approach to providing the Air Force with an *operational* weapon at the *earliest possible date.* Later, flight tests proved the soundness of the General Electric approach. On schedule, only 30 months after research and development began, the Air Force launched the free world's first operational re-entry vehicle on Thor.

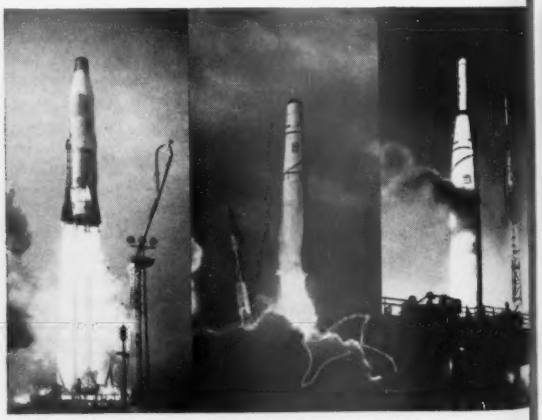
Missile and Space Vehicle Department engineers were also able to make important advances on other fronts associated with the re-entry challenge. Complex re-entry vehicle ground support equipment was developed; rocket-sled tests aided in solving fuzing problems. It was also necessary to build one of the country's most advanced data processing and computation centers to keep pace with the need for rapid processing of Air Force re-entry data.

PRODUCTION ON SCHEDULE—To prepare for Thor missile re-entry vehicle production, General Electric acquired and developed special manufacturing facilities and techniques. Proof of the smooth, rapid transition from research and development to production is the fact that Thor re-entry vehicles have passed *all operational qualification tests* and are being delivered on schedule to the Air Force for air lift to key overseas bases.

ADVANCED NOSE CONE DEVELOPMENT—Meanwhile, development continues on more advanced re-entry vehicles. Last year, one such G-E re-entry vehicle, the Thor-Able, successfully re-entered at an ICBM range of over 5500 nautical miles. With more than four years of success as an associate contractor on the Atlas, Thor and other programs, *General Electric is the leader in re-entry vehicle development and production experience.* This proven competence will continue to grow as MSVD applies its re-entry experience to the expanding list of new missile and space projects. *Missile and Space Vehicle Department of the Defense Electronics Division.* 224-50



NATION'S LARGEST PLASMA JET PLAYS KEY ROLE in providing information leading to the solution of the re-entry problem. Plasma Air Arc and many other re-entry research tools were developed by MSVD Aerosciences Laboratory scientists.

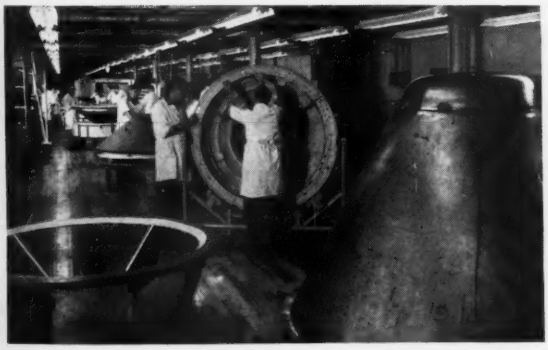


OVER 1½ YEARS OF FLIGHT TEST EXPERIENCE on Atlas, Thor and Thor-Able missiles has been gained by General Electric covering both heat-sink and ablating types of re-entry vehicles for the USAF. These three ballistic missiles are pictured above.

XUM

A GENERAL ELECTRIC RE-ENTRY VEHICLE is mated to a Thor Missile in the first SAC operational test flight exercise from Vandenberg Air Force Base.

Official U.S. Air Force photograph



RE-ENTRY VEHICLES ARE ASSEMBLED at MSVD facilities in Burlington, Vt., for both THOR and ATLAS ballistic missiles.

These Free Booklets Describe MSVD Ballistic Missile Re-entry Vehicle Work.

Indicate the brochures that you would like to have and send to: Section D224-50, General Electric Co., Schenectady, New York.

Capabilities of G.E.'s Missile and Space Vehicle Department	**GEA-6904A**
Space Technology Progress	**GEA-6876**
Heat Sink Nose Cone	**PIB-2**
Design and Fabrication of Re-entry Vehicles	**GER-1583**
Heat Protection of Re-entry Vehicles	**GER-1582**

Progress Is Our Most Important Product

GENERAL ELECTRIC

That's a precision-forged Alcoa Aluminum wing root you see in the near edge of Martin Mace's wing panel. It means the surface-to-surface tactical missile can travel to launching sites compactly, wings unattached. It means that the wings can be field mounted, ready immediately for full flight performance.

BEFORE YOU: THE "SEVENTH MIRACLE"

Seven interchangeable subcomponents comprise the TM-76 Mace. To mass-produce any of them, with the economies required for a mass-consumed weapon in wartime, seemed an impossible miracle not very long ago . . .

In due course, by ingenious innovations in design and production techniques, Martin engineers accomplished six such "miracles." The seventh—the wing assembly itself—was even more demanding. Consider:

Each wing panel was designed to extend 11.45 ft from a central wing root. Sweepback and negative dihedral dictate that this root conform to an intricate, twisted, compound curve . . . with tolerances within a few thousandths at every point in both contour shape and over-all thickness of the root.

Conventional production? Prohibitive. It would require either complex and costly machining on complex and costly machines (plus extensive hand-finishing afterwards), or—even more costly—custom-designed machines built for this job alone.

Working closely with Alcoa engineers, the Martin people found the answers. By precision-forging Alcoa® Alloy 7075-T6 *in two pieces*, each with a flat back, contour tolerances *within 0.005 in./in.* are attained *by forging alone.* And with such accuracy of contour, accuracy of *thickness* of the assembled two-piece root is attained simply *by slab-milling the mating surfaces!*

If you understand and occasionally *encounter* such problems, we hope you'll invite us to work with you. Contact your nearest Alcoa sales office, or write: Aluminum Company of America, 2028-E Alcoa Building, Pittsburgh 19, Pennsylvania.

For Exciting Drama Watch "Alcoa Theatre," Alternate Mondays, NBC-TV, and "Alcoa Presents," Every Tuesday, ABC-TV

Your Guide to the Best in Aluminum Value

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Engineering and Scientific Briefs from Correspondents Around the Globe

U.S.S.R. Academy Lab Finds New Pacific Depths

♦ The Soviet expedition sailing on the "Vityaz'," a floating laboratory of the Oceanographic Institute, U.S.S.R. Academy of Sciences, discovered a new maximum depth of the Pacific Ocean, according to V. Lutskiy, Lecturer of the Moscow Planetarium.

The Soviet scientists, using precision sounding devices, determined the maximum depth of the Marianas Depression to be 10,900 m. Soundings taken indicate that the depth of the Tonga Depression is 10,840 m., 200 m. deeper than the latest American estimates.

Lutskiy says that the expedition found the average current velocity at the depth of about 1,000 m. to be 10 to 12 cm. per sec., and, in some areas (for example, between the Moluccas and in the Philippine Islands), it reaches 50 to 70 cm. per sec. He reports that the water temperature taken at Tonga Depression at depths of 7, 8, and 9 km. was 0.16°, 0.11°, and 0.16°C. lower than the temperatures determined by a Danish expedition in 1952.

The "Vityaz' " has 14 laboratories for oceanographic studies, according to Lutskiy, and has sailed 220,000 miles over the Pacific Ocean.

Soviets Solve Problem in Rolling Low-Carbon Steel

♦ The Ural'skiy Institute of Ferrous Metals was given credit in a Soviet industrial publication for solving a problem encountered in sandwich rolling of low-carbon rimmed steel. Trouble had been encountered, it was explained, in separating the pack because the individual sheets stuck together and their separation required a great deal of effort and produced unnecessary waste. All attempts to prevent such conditions by adding phosphorus, silicon, or chromium failed.

The new method evolved when, during experiments with cold treatment of metals, it was found that cooling the packs to −40° to −50°C. prior to separating the sheets reduces the time and effort 30 per cent. It was noted that properties of the tin plate are regained on returning it to room temperature.

A machine to separate the packs has been designed on the basis of the cold-treatment process.

Plastics From Shale Made in Estonian Academy

♦ The Institute of Chemistry of the Estonian Academy of Sciences, after several years' work, has succeeded in developing a new multistage method of kerogen oxidation. This method makes it possible to manufacture succinic, glutaric, and pimelic acids commercially. An experimental installation, now under construction, will produce raw materials from these acids for production of plastics, synthetic lubricants, and synthetic rubber.

Kerogen can be obtained in quantity from Baltic slate, which is known to be rich in this bituminous material.

Intensity of Cosmic Radiation Studied by U.S.S.R. Specialists

♦ Results obtained by Sputnik II concerning the intensity and variations of cosmic radiation are being studied by Soviet cosmic-ray specialists. Discussions in U.S.S.R. scientific literature reveal a belief that findings may lead to corrections on the configuration of the magnetic terrestrial field in space.

Ye. L. Feynberg and L. I. Dorman, author of the excellent book *Cosmic Ray Variations* (*A/SE*, Dateline World, July, 1958), are credited with developing a theory permitting variation of the primary intensity of the cosmic radiation to be determined by measuring its intensity at various altitudes. Works on intensity of cosmic radiation were performed by Corresponding Member of the U.S.S.R. Academy of Sciences, S. N. Vernov, and scientific coworkers N. L. Grigorov, Yu. I. Logachev, and A. Ye. Chudakov. It seems likely that these scientists were associated with the satellite program since their names are mentioned in connection with a statement concerning the superior accuracy of the study of cosmic radiation by earth satellites.

An article in one U.S.S.R. periodical reports that data obtained by satellite measurements proved that, at altitudes up to 700 km., the intensity of cosmic radiation was approximately 40 per cent greater than at the 200-km. altitude. L. V. Kurnosova explains this phenomenon by the diminishing of the "shielding" action of the earth with altitude since the cosmic rays cannot penetrate the mass of the earth and the measurements at low altitudes actually deal only with radiation from "above." However, in reality, the cosmic rays have isotropic distribution in space, and, therefore, the measuring device in the satellite will register twice as many particles as the same device would indicate at altitudes of "tens of kilometers."

In addition, it was found that the intensity of cosmic radiation increases because of the diminishing influence of the terrestrial magnetic field with altitude.

Another fact of interest, Kurnosova reported, is that the lines of equal intensity of cosmic radiation in space do not coincide with the geomagnetic parallels, as was theoretically expected. Kurnosova says that there is a discrepancy between the characteristics of the terrestrial magnetic field obtained by measurements with cosmic rays and those performed from the earth's surface. Another interesting fact, she says, is the presence of short intensive bursts of cosmic rays registered by the satellite-borne devices, while the ground stations detected no notable intensity variations. She assumes that this phenomenon can be explained by bursts of solar energy produced by low-energy particles. Such bursts are apparently not detectable on the earth because of their absorption by the atmosphere.

Should these preliminary results on the inaccuracy of measurements from the earth's surface be confirmed, the Soviet investigators say, then the current charts of the terrestrial magnetic field could probably be corrected. They comment that this would contribute to increased accuracy of guidance systems for the space vehicles or missiles relying upon terrestrial magnetism as a guiding reference.

L. V. Kurnosova is associated with the Lebedev Physical Institute of the U.S.S.R. Academy of Sciences.

New Institute Is Added to Hungarian Academy of Sciences

♦ The Hungarian Academy of Sciences has established a Technical Physical Research Institute which will do research on the structure of materials. This type of research, it was stated, has been made necessary by the rapid progress of communications technology and, within this category, especially of vacuum technology.

The Applied Physics Laboratory
of
The Johns Hopkins University

Announces Appointments
for
SENIOR SCIENTIFIC STAFF

The Assessment Division of The Applied Physics Laboratory has undertaken new responsibilities and is expanding its Senior Analytical Staff. Senior Scientists in such fields as Mathematics, Physics and Physical Chemistry have in the past proven very effective in solving the types of problems involved which include analyses of tactical situations, the employment of future weapon systems and the application of the most recent advances in science and technology.

Performance of the work requires close association with scientists of other laboratories, operations research personnel of all branches of the Armed Services, and with senior military and civilian personnel.

Studies undertaken by this group will provide guide lines for the hardware research of future years. Staff members are expected to initiate ideas in support of a broad program of National Defense needs and carry them through appropriate analyses with assurance that sound results will be given consideration by the responsible agencies.

The Laboratory's locale, equidistant between Baltimore and Washington, D. C., allows staff members to select urban, suburban or rural living and either of these two outstanding centers of culture as a focal point for fine living.

These appointments offer exceptional opportunities. For information and arrangements for interview, write in confidence to:

Dr. Charles F. Meyer
Assessment Division Supervisor
The Applied Physics Laboratory
The Johns Hopkins University
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Silver Spring, Maryland

EDITORIAL

Charting the Future

It is certainly not "news" that the professional interests of the IAS membership have been changing over the past few years. The "Five Year Look" (Editorial, January 1959) gave clear evidence of the trend. A "Five Month Look" (January to May 1959) shows no slacking in the rate of change.

It has also been increasingly evident that operational plans and programs which have been satisfactory in the past are no longer adequate to meet the widely diversified needs of our membership. Only a few years ago, serving a small, compact industry developing under *evolutionary* rather than *revolutionary* processes, it was relatively easy for a few people to keep a sort of running "what's what and why," and lay plans accordingly. Today, however, with new techniques appearing almost daily, and with the rate of the accumulation of knowledge without precedent in any prior period, continuous sampling of trends and maximum flexibility of programing are essential for an organization such as this.

During the past year, with the advice and assistance of many Section Officers and many interested members, the Council and the Management of the IAS have been taking a hard look at the problem. It is obviously essential to broaden the base of representation on the Council and to improve channels of communication between membership and management if we are to receive the necessary guidance which current conditions demand. As a result of this effort, the membership will shortly be asked to vote on several changes in the IAS Constitution to make these desirable results possible.

Meanwhile, as one of the necessary steps in defining our problem, we made a preliminary survey to determine the range of professional interest of IAS members. We need to know what our customers (i.e., our members) want to make proper plans to serve them adequately. The tabulation below is the result. It is based on studies of job classification; on response to and interest in National, Regional, and Section Programs of the past few years; and on the general trend of events. We think it covers reasonably well our basic areas of interest.

A questionnaire based on this tabulation will be sent to you shortly by mail. It would be extremely useful to IAS program planners at all levels if you would indicate at that time the areas of your major interests and return the form to us. After the overall results are tabulated at Headquarters, the forms will be sent to the appropriate Sections for local program planning use. We would greatly appreciate your cooperation in this survey. It will help us to build better IAS programs in the future.

S.P.J.

AREAS OF IAS MEMBERSHIP INTEREST

SUBJECT	APPLICATION
	AIRCRAFT — MISSILES — SPACECRAFT
AERODYNAMICS AND FLUID MECHANICS	~~~~~~~~~~~~~~~~~~~~
OUTER SPACE PHYSICS	~~~~~~~~~~~~~~~~~~~~
AEROELASTICITY	~~~~~~~~~~~~~~~~~~~~
STRUCTURES	~~~~~~~~~~~~~~~~~~~~
MATERIALS	~~~~~~~~~~~~~~~~~~~~
PROPULSION SYSTEMS	~~~~~~~~~~~~~~~~~~~~
PROPELLANTS AND COMBUSTION	~~~~~~~~~~~~~~~~~~~~
NUCLEAR APPLICATIONS	~~~~~~~~~~~~~~~~~~~~
CONTROL, GUIDANCE AND NAVIGATION	~~~~~~~~~~~~~~~~~~~~
INSTRUMENTATION	~~~~~~~~~~~~~~~~~~~~
COMMUNICATION	~~~~~~~~~~~~~~~~~~~~
METEOROLOGY	~~~~~~~~~~~~~~~~~~~~
VEHICLE DESIGN	~~~~~~~~~~~~~~~~~~~~
HUMAN FACTORS	~~~~~~~~~~~~~~~~~~~~
OPERATIONAL PROBLEMS	~~~~~~~~~~~~~~~~~~~~

XUM

A review of some "classical," pilot-opinion centered, handling quality requirements and of research efforts designed to place the formulation of desirable vehicle handling characteristics into a more fundamental, system type of context. Determination of the dynamic characteristics of human pilots, both in flight and in simulator environments, has been a necessary phase in the development of a new approach.

Handling Qualities and Pilot Dynamics

Charles B. Westbrook
Wright Air Development Center
and
Duane T. McRuer, AFIAS
Systems Technology, Inc.

THE PRACTICAL USE of manned flight vehicles has always been dependent upon the matching of craft flight characteristics with the ability of a human being to operate the craft. Consequently, the attainment of proper vehicle handling qualities has posed problems of the greatest importance. The term "handling qualities" is a phrase encompassing such factors as aircraft stability and control characteristics, flying qualities, and other aircraft features intimately connected with the pilot's task of flight control.

The evolution of handling quality concepts has been influenced by a large amount of pilot opinion data and by an integrated judgment, formed by experienced pilots and engineers, as to what was needed and desired. Therefore, many of the data and the criteria which have directed the development of aircraft were, and still are, qualitative and occasionally arbitrary.

In the light of modern systems engineering, the handling quality picture undergoes a considerable change. It becomes apparent that pilot opinion, upon which "classical" handling qualities are based, is in reality a subjective expression of the overall suitability of a system consisting of a pilot and an airframe. In lieu of an adequate explanation of the mutual interaction of the pilot and the airframe, designers have used airframe characteristics as a means of cataloging pilot opinion. This procedure has been so dominant that, for piloted aircraft at least, handling qualities and airframe dynamics have been almost synonymous terms. Even the introduction of artificial feel systems and stability augmenters has not altered this situation significantly; these components have merely resulted in a modification of the older notion of airframe stability and control to the extent that "equivalent" airframes are now considered. Although the integration of such devices with the basic airframe required the systems thinking of the servomechanisms engineer, the systems nature of the handling quality problem did not receive much attention since the older approach still worked relatively well as a practical expedient. But as modern aircraft configurations became more radical, the airframe characteristics became more unconventional, and piloting became increasingly difficult; as a result, the convenient catalog of opinion versus airframe characteristics did not always apply. Therefore, an attempt to formulate a more basic approach was desirable.

A tentative effort in this direction was the initiation of a research program founded upon the fundamental overall system nature of the handling quality problem. The ultimate purpose of this program is the application

Symbols

$e^{-\tau s}$	=	Laplace transform representation of reaction time delay
$f_{n_{sp}}$	=	natural frequency of short-period longitudinal oscillation, cps
K_p	=	gain of pilot
s	=	Laplace transform complex variable
T_I	=	optimalizing lag time constant, sec.
T_L	=	optimalizing lead time constant, sec.
T_N	=	neuromuscular lag time constant, sec.
Y_p or $Y_p(j\omega)$	=	Fourier transform of pilot's describing function
ζ_{sp}	=	damping ratio of short-period longitudinal oscillation
τ	=	reaction time delay, sec.

Mr. Westbrook has been Chief of the Aero-Mechanics Branch, Flight Control Laboratory, WADC, since 1955. He was graduated from the University of Michigan (B.S.A.E.) in 1941, and until 1944 was Technical Assistant to the Chief, Engineering Division, at WADC. In 1945, he was graduated from the Air Corps Engineering School and during the following year obtained his M.S.A.E. from M.I.T. From 1946 to 1950, he was Stability and Control Engineer, Aerodynamics Branch, in the Aircraft Laboratory. For the succeeding 5 years, he served as Chief, Stability and Control Section, of the same Laboratory.

Mr. McRuer received his B.S. and M.S. degrees from the California Institute of Technology. He is President of Systems Technology, Inc., which is engaged in research, development, and consultation in the technical fields of automatic and manual control systems, aeronautics and astronautics, component and system reliability, and human dynamics. Prior to the formation of Systems Technology, Inc., Mr. McRuer was successively employed by Northrop Aircraft, Inc., and Control Specialists, Inc. For the past 12 years his major efforts have been devoted to research, development, and design of automatic flight control, navigation, fire control, and guidance equipment. In recent years he has also worked in the field of man-machine systems, from both the handling quality viewpoint and in the measurement, analysis, prediction, and simulation of the dynamic response of human pilots.

of human response data and conventional servoanalysis techniques to the design of overall systems incorporating such elements as the airframe (or other vehicle), control system, pilot, and displays.

The correlation of these two approaches to handling qualities—the subjective or pilot-opinion method and the direct or servo technique—is of vital importance. From the very nature of system problems, both approaches must lead to similar results before any really convincing applications of such analytical studies can be made. Long experience and familiarity lead one to feel that the pilot opinion data available are reasonably valid. Therefore, the results of studies applying human response data to pilot-airframe systems operating in some of the more difficult continuous-control types of task should be capable of being correlated with handling quality tests in at least a qualitative fashion.

In the following sections of this paper, some of the processes involved in the delineation of handling quality requirements in the Air Force are illustrated by a brief review of several examples of the origin and establishment of current requirements, together with some of the research techniques and the programs that have been, and are being, pursued to improve the definition of "what makes a good airplane." The pilot-opinion and the human-servo approaches to handling qualities are discussed, and recent efforts directed toward correlating these two approaches are reviewed. It is shown that this correlation work lends strong support to the thesis that many dynamic aircraft handling quality characteristics can soon be derived from fairly conventional pilot-airframe system analyses on a practical, more quantitative basis.

Classical Examples of the Development of Handling Qualities

In December, 1907, the United States Signal Corps issued the Signal Corps Specification 486 for procurement of a heavier-than-air flying machine. This specification stated, "During this trial flight of one hour it must be steered in all directions without difficulty and at all times be under perfect control and equilibrium." Between these early days and the forties, handling qualities were generally subject to the judgment (or whim) of the individual designer or project pilot. The artistic element was also evident in configuration design, and even today vestiges of this approach are still present in new design. In the latter years of this period, a single but all-encompassing statement appeared in the Army Air Corps designer's handbook: "The stability and control characteristics should be satisfactory." Thus in three decades the specification of handling quality requirements progressed from "perfect" to "satisfactory"!

The modern concept of handling quality requirements began with the collection and codification of data that resulted in the publication of Gilruth's NACA Report 755 in 1943.[1] Shortly thereafter, the first set of Air Force requirements, Specification C-1815, was issued. This was superseded in 1945 by Specification 1815A and in 1948 by Specification 1815B. The latest specification, MIL-F-8785 (classified Confidential), is based on the earlier specification.[2] Since 1945 these requirements have been fully coordinated with the Navy Bureau of Aeronautics.

The basic question that these specifications seek to answer is "What will pilots tolerate?" although, for certain requirements, the specifications reflect to some degree the question, "What do pilots like?" Partly because of these apparently conflicting aims, a common misconception on the part of aircraft designers has been to interpret the specification data as design points rather than minimum tolerable points. This misapplication has resulted in poor characteristics for certain aircraft.

More recently, another question has been asked: "What do pilots need to do their mission?" This query generally stems from the serious compromises in weight and performance imposed by attempting to meet handling quality requirements based on pilots' desires. System analyses of missions sometimes show that requirements can be substantially lower than those based on pilots' desires. As a result, present policy is to design to what pilots need, although it is necessary to include all possible needs from take-off to landing and not merely the needs during the attack phase. A further complicating factor is that aircraft have always been, and probably will still be, used for purposes other than the basic mission for which they were designed. The older requirements, based partially on pilots' desires, had included a pilot integration factor which took the variation of missions into account to some degree.

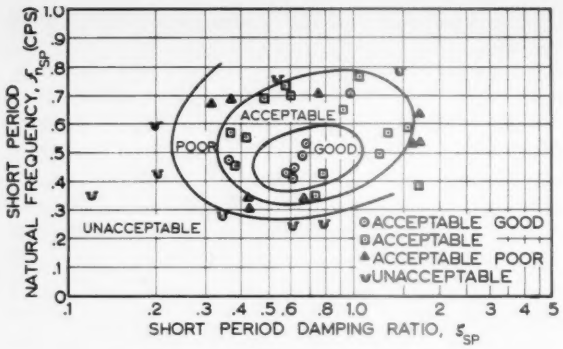

FIG. 1.

The manner in which current aircraft handling quality requirements have been derived can be illustrated by selecting several aircraft handling characteristics as examples and reviewing the thinking through the years with regard to these characteristics.

In the days of Specification C-1815, aircraft control systems were simple, direct mechanical arrangements, with only cables, pulleys, push-pull rods, and bell-cranks between the cockpit controls and the control surfaces. Requirements imposed on the manual control system were equally simple. Only friction levels were specified, and the maximum tolerable friction was based on pilot opinion. In the subsequent specifications, the general level of friction requirements has been maintained, although few aircraft have fully met these requirements. The introduction of pressurized cockpits, hydraulic valves, and design compromises in cable routing have also caused friction problems. In 1946, Phillips showed that it was possible to have bad overall dynamic characteristics even with a simple mechanical control system.[3] This led to a requirement, in Specification 1815B, that control force gradients in abrupt pull-ups be not less than those in steady turns.

As flight control system complexity increased, new problems were encountered. So many arrangements of flight control systems are possible that a limited set of requirements can hardly be expected to prevent all undesirable characteristics. Some of the important variables, even in a relatively simple system, are friction in the control valve; friction, flexibility, backlash, gearing ratio, and inertia in the control system; viscous damping and preload in the control system or valve; rate limiting of the control actuator; and the aircraft static and dynamic stability level. It has been made amply clear in actual aircraft that stability of the control system and the airframe inner loops does not assure stability of the aircraft-pilot system. Indeed, in one of the first applications of an airframe-human pilot system study, Phillips has shown that friction at the valve has been a particular source of trouble; by using a simple, pure time delay approximation of the pilot, he was able to account for control difficulties in several aircraft.[4]

The longitudinal short-period oscillation also posed handling quality problems. For the older airplanes, as long as the static stability as measured in the wind tunnel was satisfactory, good "stick-fixed" short-period damping was assured. The first opinions collected from pilots and engineers were that the response with the stick fixed was always satisfactory and so of no importance in design. But freeing the elevator could result in a lightly damped oscillation, and therefore Specification C-1815 required the motion to be damped "completely" within two cycles. Further experience led to requiring, in Specification 1815A, "complete" damping in one cycle. A refinement to a form better suited for design and flight-test use was the requirement of Specification 1815B that the oscillation damp to 1/10 amplitude in one cycle, which corresponds to a short-period damping ratio of 0.367. The stick-fixed oscillation was still held to be of no concern. These requirements were all fairly easy to meet.

Modern design trends toward higher operating altitudes, transonic and supersonic speeds, and heavier wing loadings have decreased the damping in the stick-fixed case, while, with power control systems, the "stick-free" case has disappeared. Based upon NACA experience with research airplanes that indicated pilots would tolerate considerably lower damping, the requirement in Specification MIL-F-8785 was relaxed to the point of requiring damping in both the stick-fixed and stick-free cases to only one-half amplitude in one cycle (or a damping ratio of 0.110). As service experience was gained, it was necessary to reverse this trend and increase the damping requirements considerably.

This oscillation in requirements indicated that a better understanding of what pilots need, desire, and are willing to tolerate was necessary. A comprehensive research program was therefore initiated at the Cornell Aeronautical Laboratory, Inc., under Air Force sponsorship. This program used aircraft with equipment installed to vary the "equivalent" short-period natural frequency and damping, as well as the control force and displacement gradients. Extensive flight tests were performed, obtaining pilot opinion data for various combinations of these parameters.[5, 6] Fig. 1, taken from reference 5, presents a so-called "iso-opinion plot" of the pilot opinion data obtained with constant stick force and stick displacement per unit normal acceleration.

Contrary to previous thinking that higher short-period frequencies would be desirable, Fig. 1 shows that pilot opinion deteriorates as the frequency is increased, at least with the short-period frequency range available for tests. This is true even when the damping ratio is favorable, at about 0.6 to 0.7. The pilot's comments at the higher frequencies reflect his opinion that the response is too sensitive and would lead to pilot-induced oscillations. But as the frequency is reduced, the pilot begins to object to the sluggish response and the initially heavy stick forces; and in the low damping ratio region, the pilot objects to oscillations in the airplane response, particularly in rough air. As the damping ratio is increased along a

moderate natural frequency level to a value of $\zeta_{sp} = 1.0$, the response becomes sluggish, the stick forces become heavy, and the stick motion to maneuver increases.

The codification of pilot opinion data as given in references 5, 6, and 7 represents the high point in the application of such opinion information. A similar systematic study of the lateral "Dutch roll" oscillation is currently receiving attention.

The Human Pilot as a Servosystem Element

It is well known that servomechanisms theory and methods make it possible to predict the characteristics of autopilot-airframe systems, such as the simple attitude-hold system shown in the block diagram, Fig. 2a. From servoanalyses of "closed-loop" systems of this sort, such factors as the stability (oscillation and divergence characteristics) and controllability (response to inputs) can be determined. Fig. 2b shows a block diagram of a human pilot-airframe system. The similarity between the two diagrams is evident and suggests the possibility of analyzing the human pilot-airframe system in the same manner as the autopilot-aircraft system. While the analogy is conceptually satisfying, there are two important conditions that must be fulfilled before any practical results can be obtained. The first is the obvious requirement that adequate response data must be available on human pilots. The second, more subtle, requirement is that these data must be of a type and in a form suitable for application using relatively conventional servoanalysis techniques. If these two conditions are satisfactorily met, then a servoanalysis approach can be used to investigate some dynamic handling quality problem areas. Finally, if the results of such servoanalyses show a reasonable correlation with pilot opinion, then a much firmer comprehension of the overall dynamic handling quality problem can be gained.

Because the implementation of the full-fledged systems approach is so dependent upon detailed knowledge of the response characteristics of the human pilot, the first phase of the Air Force program was the measurement of human operator characteristics using ground simulators. This work, initiated in 1949, was started in a group headed by E. S. Krendel at the Franklin Institute. It essentially continued in more detail the earlier studies performed by Tustin in Great Britain, and by a few others. During the same period, Mayne, Mead, Cacioppo, and Diamantides at the Goodyear Aircraft Corporation, Russell and Elkind at the Massachusetts Institute of Technology, and Ian A. M. Hall at Princeton University have performed significant experimental work in ground-based simulators.

The determination of human response characteristics is a formidable undertaking simply because of the prime virtue of the human being—his adaptability. As a practical expedient it has thus far been found desirable to emphasize various "tracking" tasks, mainly because in the tracking phases of the mission, the pilot must exert almost full attention to the continuous control of the aircraft to hold it to a proper track under the influence of external inputs. In some instances, tracking tasks have been found to be very difficult, even to the point that the pilot is extended to or beyond his limits as a system element.

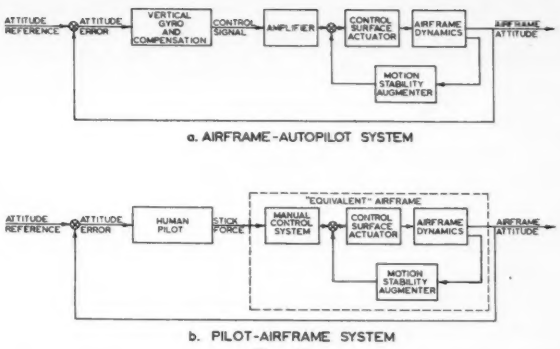

FIG. 2.

Tracking does not include those situations when the pilot flies the aircraft in an open-loop fashion. For example, the pilot flying contact in a relatively stable aircraft in smooth air is certainly not acting as an element in a closed-loop, high-performance servosystem. Tracking does include not only gunnery, rocketry, and/or bombing situations, but also closed-loop control conditions encountered in visual landing and take-offs where the pilot "tracks" the runway, contact flying in gusty air where the pilot "tracks" the horizon, and formation flying and aerial refueling where the pilot "tracks" the other aircraft. In addition, some low-altitude flight conditions and instrument landings are included.

With continuous-control tracking tasks established as important features in the successful completion of a mission, some of the more pertinent aspects of the human component in such systems must be considered. At the outset, it can be said that human behavior in closed-loop tracking tasks will depend upon the following factors:

(1) The characteristics of the controlled element (the "equivalent" airframe, display and geometry dynamics, etc.). The pilot, to be successful at all, must *adapt* his transfer or operating characteristics to a form consistent with the dynamic stability of the overall system.

(2) The particular types of inputs imposed upon the pilot-airframe system, and their degree of predictability.

(3) The actual individual reaction time, threshold, time lag, etc., of the pilot during the particular operation. There are variations in these characteristics between one individual and another, and even within a single individual at various times.

(4) The motivation, attention, previous training, and general psychological condition of the pilot at the time of the operation.

From these considerations, it can be understood intuitively that the human being is a mechanism which adapts itself, in some way, as a function of the inputs imposed and the elements controlled, and which may

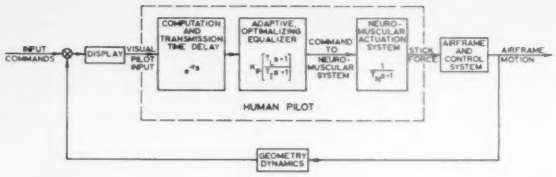

FIG. 3.

have fairly wide individual variations in the transfer characteristics adapted.

Reference 8 examines all presently available data on human response characteristics (with the exception of those given in reference 11) which are applicable to the overall system-analysis concept. From a correlation of these data, a consistent, usable mathematical representation of the human being has been obtained. Fig. 3 shows a block diagram of a linear model of the human operator performing a tracking task with unpredictable inputs. Here the human being's linear behavior is described in transfer function form, using Laplace transform notation. Notice that the human pilot has been divided into three blocks—the "neuromuscular actuator" system, the "communication and computation" delays, and an "equalizer." The neuromuscular block is approximately represented by a first-order lag between the command to the nerves and muscles and the response in stick force. This part of the overall pilot is actually at least a second-order system since equivalent masses and springs are involved, but the first-order approximation is normally adequate in the frequency ranges of interest. The pure time delay represented by the $e^{-\tau s}$ term is due to sensor excitation (e.g., the retina in the visual case), nerve conduction, and computational lags. For either single or dual input-output tasks, with random appearing inputs, this reaction time delay τ has been found to be relatively constant and unalterable.

The equalizer, as implied by its name, represents that adaptive capability of the human being that allows man to control many differing dynamic devices. Its function is the modification of the stimulus signal into a suitable neuromuscular command which is properly scaled and phased for optimum overall man-machine system operation. It has been found from almost all the currently available data that the equalizer can be represented by a gain K_p and a lag-lead or lead-lag element—i.e.,

$$\text{equalizer characteristics} = [K_p(T_L s + 1)]/(T_I s + 1) \quad (1)$$

Under very special circumstances a second lead term can be developed by highly skilled pilots. The human output feeds into the airframe control system block and then through the geometry block, closing the system loop.

In Fig. 4, the pilot's characteristics are represented by two categories—those that are relatively alterable and constant and those that are appropriately adjusted as a function of the particular task. The unalterable characteristics of the human being represent his most serious liabilities as a servoelement and restrict the attainable overall system performance. These include the reaction time delay $e^{-\tau s}$ which in many practical problems is the dominant factor. The form of the equalizer is adapted to one consistent with the best performance of the task within the limiting forms shown. For example, the equalizer could be pure gain, gain plus a lead, gain plus a lag, or the full gain-lead-lag shown. The equalizer also possesses an optimalizing characteristic of such a nature that, after the form is fixed as required by the controlled-element transfer function, the "constants" within the adapted form are adjusted for some optimum type of operation in a fashion analogous to that used in minimizing rms error in a more conventional servosystem. The price paid for all of this adaptability is the $e^{-\tau s}$ reaction time delay term.

The total linear transfer characteristics can be described approximately by Eq. (2), in a form entirely analogous to those used by servo engineers.

$$Y_P = \frac{\text{pilot's force output}}{\text{pilot's visual input}} = \frac{K_p e^{-\tau s}(T_L s + 1)}{(T_I s + 1)(T_N s + 1)} \quad (2)$$

For a given task, the pilot transfer function generated is very similar to the one that a flight control engineer would select if he were given an airframe to control and an autopilot which had the same transfer function as shown in Eq. (2), with external knobs enabling him to adjust the lead and lag time constants T_L and T_I and the sensitivity K_p. In this quality of variable sensitivity and equalizer characteristics, the unique characteristics of man as a servo element are evident. It should be noted that the human being is the archtype of that category of servo devices which has recently received considerable attention—the adaptive, optimalizing type.

In addition to the quasi-linear autopilot behavior described above, the pilot's output also contains an additional quantity which can be termed the *remnant*—that portion of the pilot's output which is not "explained" by the linear transfer function discussed previously. The current conception of this pilot motion component is not so well-defined as would be desirable, although several possible "explanations" compatible with all known data are discussed in reference 8. The remnant is the principal contributor

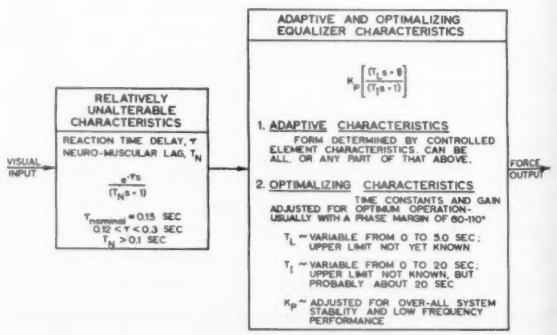
ADAPTIVE AND OPTIMALIZING EQUALIZER CHARACTERISTICS
RELATIVELY UNALTERABLE CHARACTERISTICS
REACTION TIME DELAY, τ
NEURO-MUSCULAR LAG, T_N
VISUAL INPUT
FORCE OUTPUT
1. ADAPTIVE CHARACTERISTICS
FORM DETERMINED BY CONTROLLED ELEMENT CHARACTERISTICS, CAN BE ALL, OR ANY PART OF THAT ABOVE.
2. OPTIMALIZING CHARACTERISTICS
TIME CONSTANTS AND GAIN ADJUSTED FOR OPTIMUM OPERATION-USUALLY WITH A PHASE MARGIN OF 60-110°
T_L ~ VARIABLE FROM 0 TO 5.0 SEC; UPPER LIMIT NOT YET KNOWN
T_I ~ VARIABLE FROM 0 TO 20 SEC; UPPER LIMIT NOT KNOWN, BUT PROBABLY ABOUT 20 SEC
K_p ~ ADJUSTED FOR OVER-ALL SYSTEM STABILITY AND LOW FREQUENCY PERFORMANCE

FIG. 4.

to the quasi-periodic behavior observed in tracking records and is a major cause of tracking error.

An additional output quantity shown by some pilots in some tasks is the phenomenon of "dither."[9] This is an individual tactic which the pilot uses consciously, depending upon the task. Physically, it consists of a rapid, almost sinusoidal oscillation (1.2 to 1.5 cps) generated by the pilot and "added" to those portions of his output "explained" by the transfer function and remnant models considered previously. The dither action is analogous to that used in servosystems as a general linearizing technique—e.g., to reduce the effects of coulomb friction and stiction. In ground simulators it generally occurs in situations where such a technique appears to the pilot to be an applicable tactic. Its existence in flight is hypothetical although it has been proposed as a "test signal" to excite the system as a part of the adaptation mechanism.

As a final item on human response data, it should be noted that all the above comments are based upon measurements taken in ground-based simulators. In an attempt to determine the degree of possible differences between ground simulator and flight environments, a flight validation program was undertaken at Princeton University. In this program, a Navion aircraft was used as both a flight vehicle and, in conjunction with analog computer elements, a ground simulator. Essentially identical ground and flight, lateral and longitudinal visual tracking tasks were given to a series of pilots, and their characteristics were then measured in both environments. The results of these experiments, interpreted in terms of Eq. (2), were (as given in reference 10):

(1) In longitudinal control, the pilot's flight gain, K_p, was approximately one-half that in the ground simulator.

(2) In both lateral and longitudinal control, the pilot's effective reaction time delay was approximately 0.15 seconds longer in flight than in the simulator.

(3) The flight remnant was larger than the simulator remnant in both lateral and longitudinal control.

All other pilot characteristics were the same in both the flight and the simulator environments. Although the psychological causes underlying these observed differences have not been rigorously defined, they are believed to be due primarily to flight-simulator differences in "set to respond" and conflicting visual demands, and to the effective presence of accelerations in the airborne case.

The single most remarkable thing to be gathered from the foregoing discussion is the exceptional capability of the human being as an adaptive servo element. When one considers also the human being's ability to even further modify his characteristics for more predictable inputs, the comparison of a pilot with even a very sophisticated autopilot is heavily weighted in the human being's favor for many flight control problems.

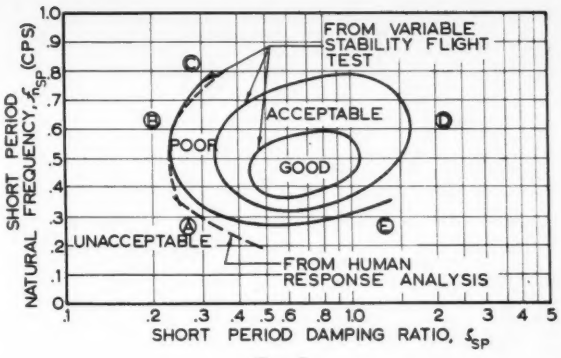

FIG. 5.

Correlation of the Two Approaches

The handling qualities examples reviewed above were selected to illustrate a point regarding the human-servo approach and its relationship to handling requirements.* The applicability of the human-servo approach to the short-period longitudinal oscillation is clear-cut. In view of the extensive data obtained and catalogued on "iso-opinion" plots, a concentrated attempt has been made to obtain correlation between these pilot-opinion data and what might be expected from the human-servo model. In Fig. 5, where the contours from the "iso-opinion" plot presented in Fig. 1 are reproduced, there appear to be three regions where pilot-airframe system stability is an important factor in pilot opinion. These are the regions labeled A, B, and C, for which pilot comments are summarized in Table 1. In regions D and E (not shown in the table), the comments indicated that pilot objections centered about heavy stick forces and very sluggish response.

The human-pilot adaptive model discussed above has been used in conjunction with aircraft characteristics in a crude analysis resulting in the dashed line on Fig. 5. The shape of this curve depends to a great extent upon the value of reaction time delay, and the

* It should be noted, however, that numerous requirements currently necessary and included in specifications are clearly not amenable to treatment by present servoanalysis, human-response techniques. Such things as rudder power for the one-engine-out case and cross-wind landing requirements are examples.

TABLE 1

Region		Pilot's Comments B-26	Pilot's Comments F-94
A	low ζ_{sp} low $f_{n_{sp}}$	Sluggish and oscillatory	Sluggish initial response, then oscillatory. Pilot overcontrols, tends to exceed load factor.
B	lowest ζ_{sp} medium $f_{n_{sp}}$	Dangerous oscillation	Initial response fast and abrupt. Constant short-period oscillation which pilot excites. Must let go of stick to damp out oscillations. Overshoots load factor. Requires constant attention.
C	medium ζ_{sp} highest $f_{n_{sp}}$	Fear of gusts; response too fast; forces too light	Initial response fast and abrupt. Small stick zero, light forces around center. Sensitivity causes pilot-induced oscillations.

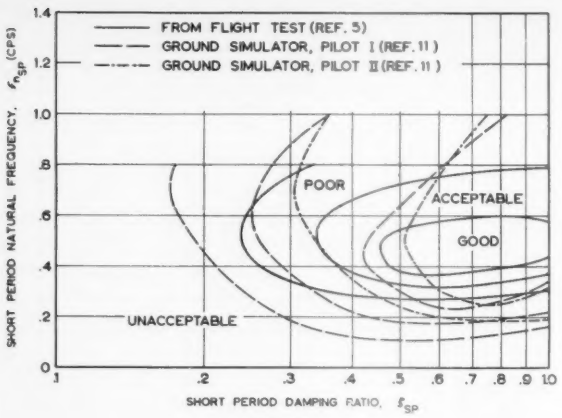

FIG. 6.

one shown was based upon a τ value consistent with that measured in other tests for the particular pilot who generated the opinion data. The stability boundary curve shown is not particularly rigorous, but the correlation, in curve shape alone, is encouraging. One can further show analytically that the "good" region corresponds to conditions where the "analog pilot" is allowed considerable variation in lead time constant and closed-loop response without having a closed-loop airframe-pilot system instability. In other words, the "good" region is one where the analog pilot can easily be adjusted to obtain fast, stable time responses. The "acceptable" and "poor" regions correspond to those conditions where greater restrictions must be placed upon the pilot analog than is the case in the "good" region to obtain even moderately fast and stable closed-loop response.

While these findings are by no means ironclad, they do point up an exceedingly important concept—quite simply, that *pilot opinion of an airframe configuration is closely correlated with closed-loop performance, and hence to some extent with the transfer characteristics and parameters adapted by the pilot to control the configuration.* Essentially complete verification of this statement, and consequently evidence of close correlation between the two approaches to handling qualities, has been obtained for the longitudinal short-period case. As part of the overall Air Force program, Ian A. M. Hall at Princeton University duplicated the Cornell Aeronautical Laboratory variable stability, longitudinal flight, airframe characteristics in a series of tracking tasks conducted in a ground simulator environment.[11] During these tests two pilots were used, and both opinion and pilot response data were taken. The pilot opinion data are shown in Fig. 6. It will be noted that the opinion plots of Fig. 6 agree quite well with those shown in Fig. 1. The most interesting results derived from Hall's tests, however, are the significant changes in the pilot's transfer function with opinion. Although a complete analysis of all these results has not yet been completed, the findings do indicate that the human-operator models can be interpreted to give results consistent with those obtained by pilots while airborne. They also indicate that the ultimate application of a systems approach to handling qualities is an extremely promising field.

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Part I discussed the space motions of the earth. Of the many known motions, the angular rotation rate about the polar axis—15.04107 deg. per hour—is the principal one seen by an inertial navigation system. The others either are too small to be of significance or, because they are caused by mass attraction of other bodies, are not sensed by inertial sensors. Part II discusses the shape of the earth and its effect on inertial navigation parameters.*

The Earth and Inertial Space

Part II—Shape of the Earth

Richard H. Parvin, MIAS
Minneapolis-Honeywell Inertial Guidance Center

THE EARTH, as if it were a fluid sphere set into rotation, has assumed the shape of a spheroid or an ellipsoid of revolution about its minor (polar) axis. The ellipticity of the earth [$(a - b)/a$, where a and b are the equatorial and polar radii] is calculated to be 1/297, with a polar radius of 3,432.458 nautical miles and an equatorial radius of 3,444.054 nautical miles.[1] These are the dimensions of the International Spheroid, agreed in 1924 to best define the shape of the smooth earth. Recent determinations indicate the International Radius to be too large by some 300 to 450 ft. An earlier calculation, the Clarke Spheroid of 1866, has slightly different dimensions,[2] and geographical positions in the United States are based upon this configuration (polar radius of 3,432.281 nautical miles and equatorial radius of 3,443.956 nautical miles).

The Nautical Mile

The International Nautical Mile of 1954 is meant whenever "nautical mile" is referred to herein. It is now the accepted unit of most of our Government agencies. However, many older references are in existence, and the older units will appear in new publications occasionally. Care should be taken to define the "nautical mile" where accuracy is required.[3]

International Nautical Mile: exactly 1,852 m., 6,076.103 U.S. ft.
Admiralty Nautical Mile: 1,853.1811 m., exactly 6,080 Br. ft.
U.S. Nautical Mile: 1,853.2487 m., exactly 6,080.2 U.S. ft.

Similarly, the "knot" should be defined as to the *particular* "nautical mile per hour." The Hydrographic Office publication *Useful Tables, H.O.9* is being revised to use the International Nautical Mile throughout and will be published later this year. Coast and Geodetic Survey publications are using this unit.

Parameters Affected by Ellipticity

This flattening of the earth at the poles affects inertial navigation system design in several ways. The radius of the earth depends on the latitude according to the formula[1]

$$\rho = a(0.998320047 + 0.001683494 \cos 2\phi - 0.000003549 \cos 4\phi + \dots)$$

where a = equatorial radius, 6,378,388 m. or 20,926,428.0 ft., or 3,444.054 N.M.

which is plotted as Fig. 8. The length of a degree of latitude is not constant, as shown in Fig. 9.[2]

A plumb bob at the surface of the earth will not point exactly to the center of the earth but will be deflected slightly toward the equator. This effect is a composite of mass attraction and centrifugal force, Fig. 10. The mass at B, being closer, has a greater effect on the plumb bob than the mass at A. Even greater is the deflection due to the centrifugal force developed by the earth's rotation. Together these two effects cause a maximum deflection of 11 min. 35.7 sec. at latitude 45 deg. and reduce to zero at the poles and equator where the vertical passes through the center of the earth. The equation[1] for the angle between geocentric latitude (Ψ) and geodetic latitude (ϕ)

$$\Phi - \Psi = 695''.66 \sin 2\phi - 1''.17 \sin 4\phi \dots$$

is plotted as Fig. 11.

It may be wondered what effect the moon and sun have on the direction of the gravity vector since they have such an appreciable effect on the tides. It has been calculated that the angular variation in gravity

* Part I appeared in the April issue, p. 34.

The assistance of the U.S. Coast and Geodetic Survey and of the Smithsonian Astrophysical Laboratory in reviewing the technical information herein is greatly appreciated, as is the assistance of Mrs. Barbara Scott in the calculations, and Barnet Bethel in preparing the illustrations.

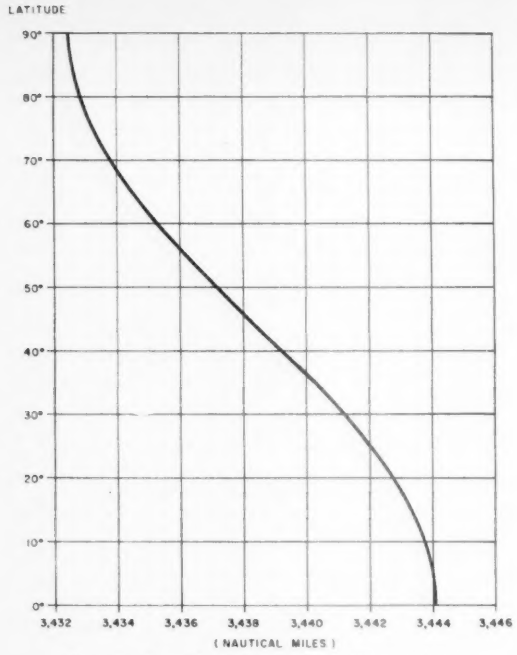

FIG. 8. Length of the earth's radius vector.

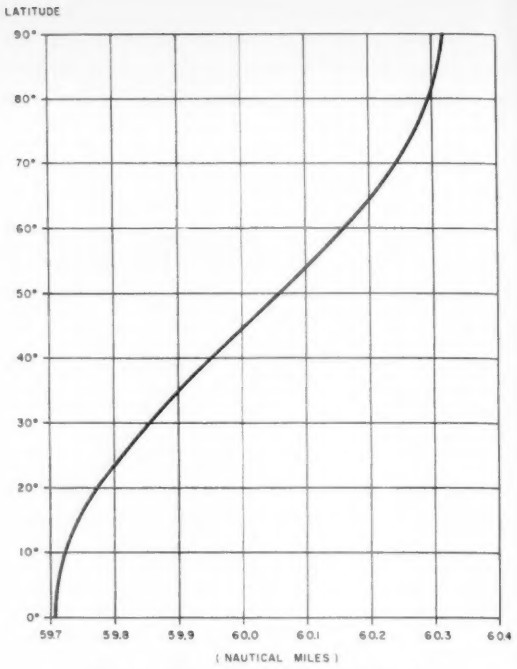

FIG. 9. Length of a degree of latitude.

due to the motions of these bodies is in the order of 0.01 sec.[4]

Not only the *direction* but also the *magnitude* of the gravity vector varies with latitude because of three effects—centrifugal force, attraction of the bulge at the equator, and the change in distance from the center of mass attraction. The International Gravity Formula[5] is

$$\gamma_o = \gamma_e(1 + 0.0052884 \sin^2 \phi - 0.0000059 \sin^2 2\phi)$$

where γ_o = theoretical value of gravity at sea level, and γ_e = value of gravity at the equator (978.04900 cm./sec.^{2} or 32.088 ft./sec.^{2}). This is plotted as Fig. 12. This reduction in gravity at the equator is sufficient for a mass to weigh 0.53 per cent more at the poles than at the equator.

The length of the Schuler period, a characteristic oscillation in earth-stabilized inertial navigation devices, is

$$T = \pi/\sqrt{g/R}$$

so this period also varies with latitude, as shown in Fig. 13.

Effect of Height on Gravity

The magnitude of gravity is diminished with height above sea level by the formula[6]

$$\gamma_h = \gamma_o - (0.00030855 + 0.00000022 \cos 2\phi)h + 0.000072(h/1000)^2$$

where h is in meters, and γ is in cm./sec.^{2} or gals. The direction of the gravity vector is deflected slightly toward the pole[7]:

$$\delta_g = 0''.000052h \sin 2\phi$$

where h is in feet.

Which "Latitude"?

With several different vertical references, there is the question of defining *latitude*.[8] The angle between the equatorial plane and the radius vector from the center of the earth is *geocentric latitude*. But the angle between the equatorial plane and the normal made by the *vertical* to the surface of the spheroid is *geodetic latitude*, as shown in Fig. 10. *Latitude* usually refers to geodetic latitude, and this is the basis for most maps and charts we use.

A third latitude to consider is *astronomical latitude*. Vertical is indicated by some gravity-sensing device such as a plumb bob, a bubble level, the horizon at sea, or the north and south level accelerometers of an earth-

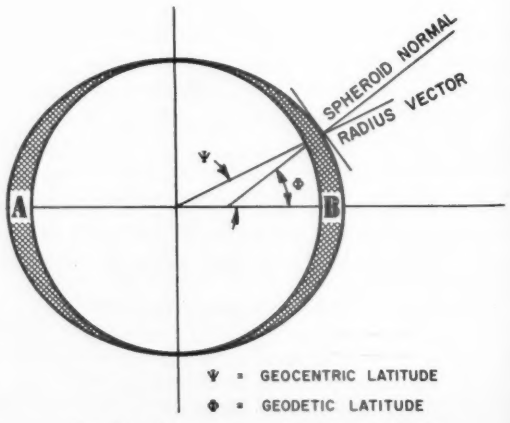

FIG. 10. Geocentric and geodetic latitudes.

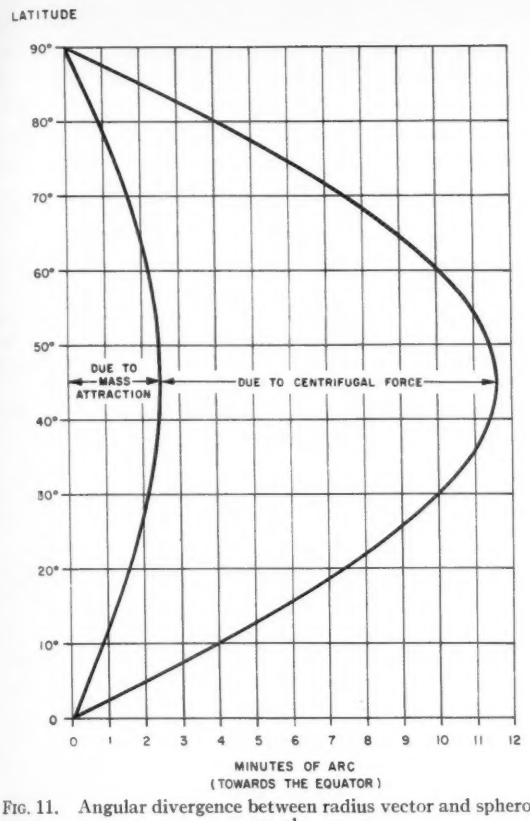

FIG. 11. Angular divergence between radius vector and spheroid normal.

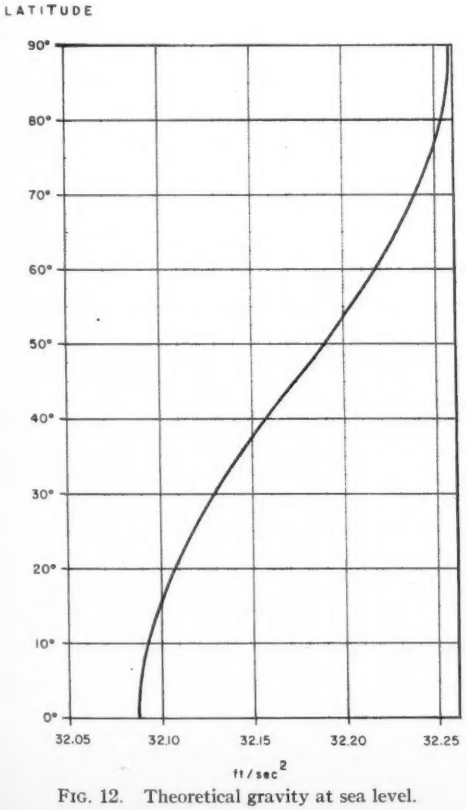

FIG. 12. Theoretical gravity at sea level.

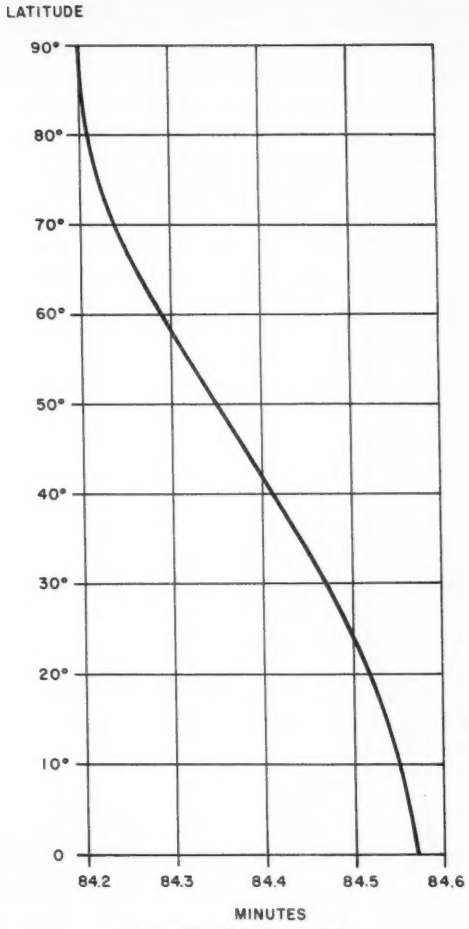

FIG. 13. Schuler period.

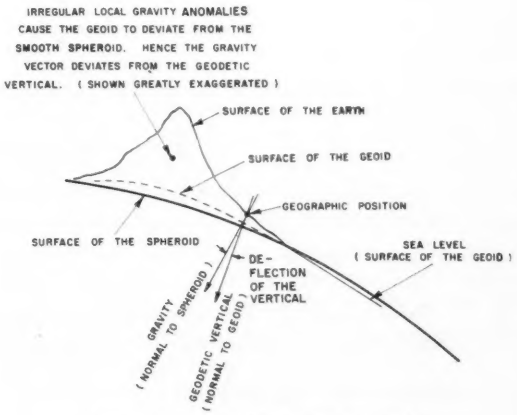
IRREGULAR LOCAL GRAVITY ANOMALIES CAUSE THE GEOID TO DEVIATE FROM THE SMOOTH SPHEROID. HENCE THE GRAVITY VECTOR DEVIATES FROM THE GEODETIC VERTICAL. (SHOWN GREATLY EXAGGERATED)
SURFACE OF THE EARTH
SURFACE OF THE GEOID
GEOGRAPHIC POSITION
SURFACE OF THE SPHEROID
SEA LEVEL (SURFACE OF THE GEOID)
DE-FLECTION OF THE VERTICAL
GRAVITY (NORMAL TO SPHEROID)
GEODETIC VERTICAL (NORMAL TO GEOID)

FIG. 14. The spheroid and the geoid.

referenced inertial system (which sense no component of gravity when the stable platform is level). These indications are influenced by any local gravity anomalies that may be present due to irregular distribution of the earth's mass at or near the surface. These deflections of the vertical rarely exceed 30 sec. in continental United States but have been measured up to about 1 min. in the vicinity of Puerto Rico.

Astronomical latitude, reference to local vertical, can be measured on the spot. *Geodetic* latitude can be determined only when local station error is known—by tying into a triangulation network covering a large area. This means that the geographical positions of places that cannot be tied into a network—such as remote islands—may be improperly located on charts because the station error is unknown. We can extrapolate positions by triangulation halfway around the world more precisely than they can be determined by field astronomy.[9]

If all anomalies were known, a useful figure called the *geoid* could be described.[10] The geoid is the surface that is perpendicular to the direction of gravity at all points. The surface of a smooth sea is free to flow and hence assumes the shape of the geoid. If little canals were dug from ocean to ocean, the surface of the water in the canals would be mathematically irregular because of local anomalies (Fig. 14). This equipotential surface is the geoid.

Until local anomalies are known much better, the exact shape of the geoid will remain unknown. Therefore, we do not yet know whether the International Spheroid is the "best fit" of a mathematical ellipsoid into the geoid. It is believed the geoid will be found to stay within ±200 m. of the "best fitting" ellipsoid.[11]

Satellite Data

International cooperation in the field of geophysics is quite good. The efforts of the IGY and the satellite projects are expected to advance considerably the accuracy of man's knowledge of the earth's shape and space motions. The inertial system designer uses this basic information. Thus, he is able to apply the information received from inertial navigation's two basic sensors—the accelerometer and the gyro—to the solution of the navigation and guidance problem.

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"The necessity for working with probes in thin boundary layers brought with it the desirability of a technique for observing flow processes in the vicinity of the probes. With this end in view, the microschlieren apparatus was developed."

Microschlieren

A Technique for the Study of Details in Compressible Flow

Walter S. Bradfield, AIAS, and Joseph J. Sheppard, Jr., MIAS
University of Minnesota

FOR SOME TIME, the writers have been engaged in research involving the use of instrument probes in thin boundary layers. The necessity for working with probes in thin boundary layers brought with it the desirability of a technique for observing flow processes in the vicinity of the probes. With this end in view, the microschlieren apparatus was developed. The instrument implements a technique that provides high magnification of the small field which one wishes to study and sufficient contrast for the rendition of details in this field. A sharp focusing property minimizes the effect of regions fore and aft (along the optical axis) of the subject field on the final image. Particular emphasis is placed on high aperture, short focal length objectives working with short optical path lengths. This permits investigation of flow regimes outside the range of commonly used visualization techniques. The optical system may be used as a focused shadowgraph, as a Toepler schlieren, and also as a phase microscope to produce an image of the flow phenomena.

Walter S. Bradfield, Senior Staff Scientist in Fluid Dynamics, Convair Scientific Research Laboratory, received his Ph.D. degree from the University of Minnesota. Prior to joining Convair, Dr. Bradfield was Project Scientist in convective heat transfer, thermodynamics, viscous compressible flow, and nonstationary compressible flow at the University of Minnesota. Dr. Bradfield's current research interests are high-speed chemically reacting boundary layers and film boiling phenomena in high-speed liquid flows.

Joseph J. Sheppard, Jr., Staff Scientist in Fluid Dynamics, Convair Scientific Research Laboratory, received his M.S. degree from the University of Minnesota. Prior to joining Convair, Mr. Sheppard was a Senior Engineer engaged in research on laminar and turbulent boundary layers at supersonic speeds at the University of Minnesota, Rosemount Aeronautical Laboratories. Mr. Sheppard's current research interests are high-speed chemically reacting boundary layers and physical optics.

Description of the Apparatus

In schlieren systems commonly used in the study of flow fields, the image of the field on the photographic negative is several times smaller than the object being viewed. To obtain detail of the small fields under consideration, which normally would be invisible to the unaided eye, the present optical system gives a 6 to 40 power image on the negative of a field approximately 3/4 to 1/4 in. in diameter, with a possible overall magnification of approximately 20 to 100 power in the final positive print.

The high magnification complicates the problem of providing sufficient sensitivity, which we may define qualitatively as the ability of the system to render visible spatial variations in the properties of the flow field. For example, other conditions being the same, the effect of increasing the magnification of a particular field is to decrease the contrast in the image. Adequate sensitivity is provided in the present instrument by the use of high aperture, quality objectives well corrected for this application and the use of an axially symmetric design to minimize aberrations. The small, axial, circular pinhole source enhances sensitivity by sharpening the images of localized phenomena and providing uniform contrast in images of extended areas with constant flow properties. This feature represents a distinct departure from customary schlieren practice, and is the only source configuration which has a sound theoretical basis[2] for use with the phase contrast technique when applied to flow fields.

The focused shadowgraph (or brightfield microscope) is insensitive, as expected, and is reported solely for reference. This technique should not be confused with the well-known nonfocused shadowgraph which is inapplicable here, as it provides no means for obtaining the high magnifications necessary. Both the Toepler schlieren and the Zernike phase contrast techniques

The work reported in this paper was supported by the Office of Scientific Research, ARDC, under Contract Number AF 18 (600)-384.

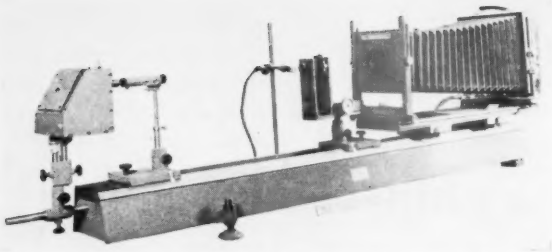

FIG. 1. Photograph of microschlieren system.

exhibit satisfactory sensitivity, as shown by the results presented in the next section.

When examining local regions of a flow field of considerable depth in the direction of the optical axis of the microschlieren system, it is desirable that the instrument have a small depth of field. Phenomena fore and aft of the region under study—to the extent they appear in the final image—reduce contrast and hamper an interpretation of the image. The present instrument exhibits a quite shallow depth of field by virtue of the large working numerical aperture of the schlieren objective. The practical depth of field, defined as the separation required to defocus completely a small localized aerodynamic disturbance, is approximately 1 mm. (about 40 mils), for a typical objective lens working at 30 power.

Flow phenomena generally exhibit some instability; thus, to avoid a blurring effect and provide adequate resolution, it is usually necessary to make photographs with extremely short exposures, of the order of a few microseconds. The B-H6 high-pressure mercury arc lamp source used will make suitable spark exposures with durations of 6 to 12 microsec. Of course, other spark sources are available with much shorter duration, but these generally cannot be run continuously and, hence, are not as versatile as the B-H6 in this application.

Despite the high magnifications possible with the microschlieren system, which normally indicates very short working distances, the photomacrographic schlieren objectives* provide a range of working distances from $1^1/_2$ to over 5 in. Thus, the instrument may be used with wind tunnels and flow channels of reasonable size.

Fig. 1 presents a photograph of the microschlieren system. The light source is the B-H6 high-pressure mercury arc lamp. This lamp has the distinct advantage that it may be burned continuously or flashed, the flashes having a duration of the order of 10 microsec.

The condensing lens, attached to the lamp housing, is an ordinary 10-power microscope objective, and focuses an image of the arc lamp on a pinhole, the latter serving as an effective illumination source. The collimator consists of this 10 mil diameter pinhole in the focal plane of an achromatic collimating lens.

* *Photomacrography* is the enlarged photography of small objects by the use of a long bellows camera and a lens of short focal length corrected for this use. *Photomicrography* is the photography of extremely small objects through a microscope.

The object space between the collimator and the schlieren objective lens assembly is adjustable so that the system may be adapted to the particular application at hand. In Fig. 1, the object space is occupied by a small free jet made from an ordinary brass flare cap.

Just beyond the object space is the microschlieren head. It consists essentially of the objective lens and the plate holder in the focal plane of this lens.

The objectives are short focal length lenses, designed especially for photomacrography. Lenses with focal lengths of 32, 48, 72, and 120 mm. are interchangeable, with field sizes of approximately 1/4 to 3/4 in. Magnifications up to 40 power are obtainable with these lenses.

The plate holder, which accepts either a schlieren knife edge or a phase plate, is attached to the same base as the objective mount. The schlieren knife edge is constructed of 10 mil thick brass shim stock. The phase plates consist of 20 by 25 mm., 1/2 mm. thick optical glass plates on which the conjugate area is formed by depositing titanium and magnesium fluoride.

An 8 by 10 commercial view camera with a bellows draw of 30 in. serves as the film holder. The maximum bellows draw is the limiting factor on the magnification obtainable with the objectives in this apparatus. Since the camera contains no optical components, loading and unloading film does not endanger the optical adjustments of the system. The entire microschlieren assembly is mounted on a precision lathe-bed type optical bench.

An optical diagram of the microschlieren system is presented in Fig. 2. The reader is cautioned that the optical treatment in Fig. 2 differs from that customarily used in interpreting schlieren systems wherein the refraction or "bending" of light "rays" in object space and their subsequent displacement in the knife edge plane are considered. This type of analysis, based on geometrical optics, does not admit the phenomena of interference and diffraction. However, the image formation in the high numerical aperture, short focal length microschlieren system with the attendant modifications in the back focal plane of the objective depend so intimately upon the phenomena of diffraction that even a qualitative explanation of the instrument must involve diffraction. Thus, we use what is essentially the Abbe diffraction treatment of the formation of an image by an objective, admittedly qualitative in Fig. 2.

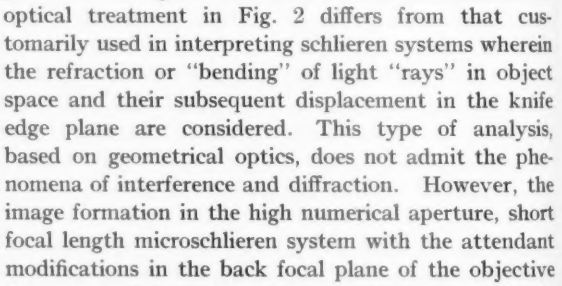

FIG. 2. Optical diagram of microschlieren system.

According to this method, the parallel light incident on the object space is partially diffracted by a small disturbance (nonhomogeneity in optical path). The diffracted portion of the incident light may be treated as originating at the disturbance and, hence, is focused by the objective at the conjugate (or film) plane. The undiffracted light, being parallel, is focused in the focal plane of the objective and thence spreads out to illuminate the film plane uniformly.

The two wave systems, which are differentiated by shading in Fig. 2, combine in the film plane to form an image of the object. Further, one notes in Fig. 2 that in the focal plane of the objective lens the two systems have little area in common, the undiffracted waves being highly focused on the optical axis. Hence, a knife edge or a phase plate may be inserted at this plane to intercept selectively and/or change in relative phase a portion or all of either or both wave systems independently. The "modifications" of the waves at this plane determine the detail and contrast in the final image or film plane. The insertion of a knife edge for Toepler schlieren results in an interception of one half of the diffracted system and selective portions of the focused undiffracted light, and the appearance of the resultant image is well known. Zernike phase contrast results from the insertion of phase plates which partially absorb the focused undiffracted light and shift it in phase with respect to the diffracted light which is unaffected. The appearance of the resultant image is generally less familiar to the experimenter in fluid mechanics. Clear and comprehensive discussions of this technique are found in references 1 and 2.

Some Typical Applications

The main usefulness of the microschlieren is for making detailed flow studies of small isolated regions of flow fields. In the object space of Fig. 1 is shown a setup consisting of a 1/32-in. orifice drilled into a 1/4-in. brass flare cap. Mounted to this open jet configuration is a common sewing needle.

The series of flow pictures in Fig. 3 shows the shock system over this sewing needle and provides a comparison of focused shadowgraph, schlieren, and phase contrast techniques. The flow conditions for all three pictures were essentially the same. The stagnation pressure was approximately 75 psig and the jet discharged to atmospheric pressure. The magnification is 36 power.

The bow shock and a few of the stronger shock waves on the needle itself can be seen in the shadowgraph, Fig. 3(a). The circles appearing in the field are dust motes on the optics.

Fig. 3(b) is a schlieren photograph of the same object and the same flow taken with 1/2 knife edge. Considerably more detail can be seen in this picture than in the shadowgraph, although blurring due to unsteadiness in the jet flow obscures much of the detail. The exposure time for the photographs on this figure was approximately 1/2 sec. for the schlieren and phase and

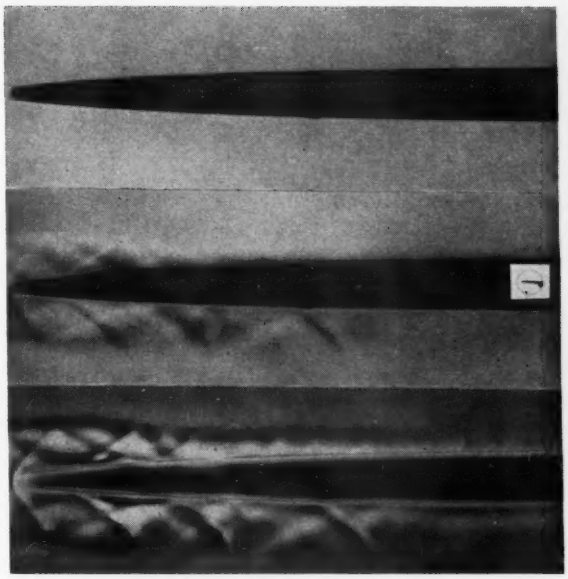

FIG. 3. A comparison of shadowgraph, Toepler schlieren, and Zernike phase contrast microschlieren techniques (magnification 36×). (a) Shadowgraph of ordinary sewing needle in air jet. (b) Schlieren, 1/2 knife edge. Same flow as (a). (c) Phase contrast, 1/4 λ phase shift and 1.3 % transmissivity. Same flow as (a).

1/10 sec. for the shadowgraph. One notes that the diffraction pattern on the upper side of the needle is cut off by the knife edge in the schlieren picture.

Shown for comparison with shadowgraph and schlieren is the phase contrast technique, Fig. 3(c). By comparison with Fig. 3(b), considerably more contrast and detail in the flow are shown for this particular flow field. One notes also that the reversal in contrast about the axis of symmetry, characteristic of the schlieren, is absent in the phase contrast photograph. However, the phase contrast method does exhibit a mildly troublesome inherent characteristic—namely, the halo clearly visible about the boundaries of the needle in Fig. 3(c). The sole practical importance of the halo is a reduction in contrast of the detail in the region it occupies.[2]

The lumps on top and bottom of the needle near the tip which show up in both the schlieren and phase photographs are oil droplets. The droplet on the upper side of the needle in Fig. 3(b), for example, is approximately 2/10 mm. in length and roughly 1/1000 of an inch thick. The shock wave generated at the leading edge of this droplet can be clearly seen. It can also be seen that the droplet has settled just downstream of this shock wave which originates from the lip of the jet.

The comparison of the schlieren and phase contrast techniques in Fig. 3 shows that the phase contrast technique brought somewhat more contrast and detail to the photograph than did the Toepler schlieren technique. At lower densities (the densities for the photographs in Fig. 3 are somewhat higher than ambient atmospheric density), the phase contrast technique, being more flexible, should generally show a

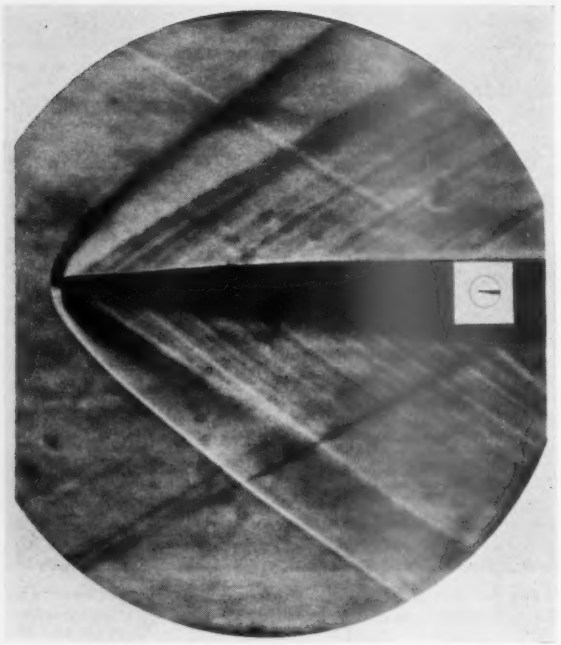

FIG. 4. 1/4 knife-edge schlieren of boundary-layer total temperature probe in air jet (edge view) (magnification 22×).

greater advantage with a phase plate "tailored" to the flow field under observation. Until more extensive investigation produces guides for the selection of phase plate characteristics for a particular flow field, the authors suggest the use of plates with a $\lambda/4$ phase shift and transmissivities of 1 to 12 per cent of the undiffracted light. Practical hints for construction of such plates are given in reference 2.

Typical photographs from investigations of two additional flow fields using the schlieren technique are presented here to give further indication of the quality of the results available with the microschlieren system. Further, whereas the exposures in Fig. 3 were quite long (1/10 sec.), the results in Fig. 4 and 5 were obtained by flashing the B-H6 source, giving an exposure of approximately 6 microsec.

Fig. 4 shows the flow field about a small boundary-layer total temperature probe in an air jet at a Mach Number of 1.95. A full sized sketch of the probe tip in the photograph is shown for comparison. The secondary shock of the tip can be seen quite clearly. Due to the large number of secondary wavelets, the variation in Mach Number behind the normal shock wave can be traced qualitatively rather well in this picture. The microschlieren system should prove quite useful in observing the flow field about such probes while traversing boundary layers.

Fig. 5 shows a microschlieren photograph of a portion of the flow field about a 20° included angle cone in a Mach Number 2.3 nitrogen jet. The region involves a shock-wave boundary-layer interaction, and also shows the shock system from a small voltage pick-off probe used in heat-transfer measurements with the model. The detail present in the photograph is quite remarkable, and clearly indicates the usefulness of the present technique for detailed studies of such interaction phenomena. One notes that the boundary layer on the model upstream of the shock-wave impingement is clearly visible although only about 0.006 in. thick.

Conclusions

A more detailed discussion of the flow phenomena in the photographs just presented is not in order here. The pictures are presented to acquaint the reader with the type and quality of results obtainable with the microschlieren technique. Since the instrument is

(*Continued on page 56*)

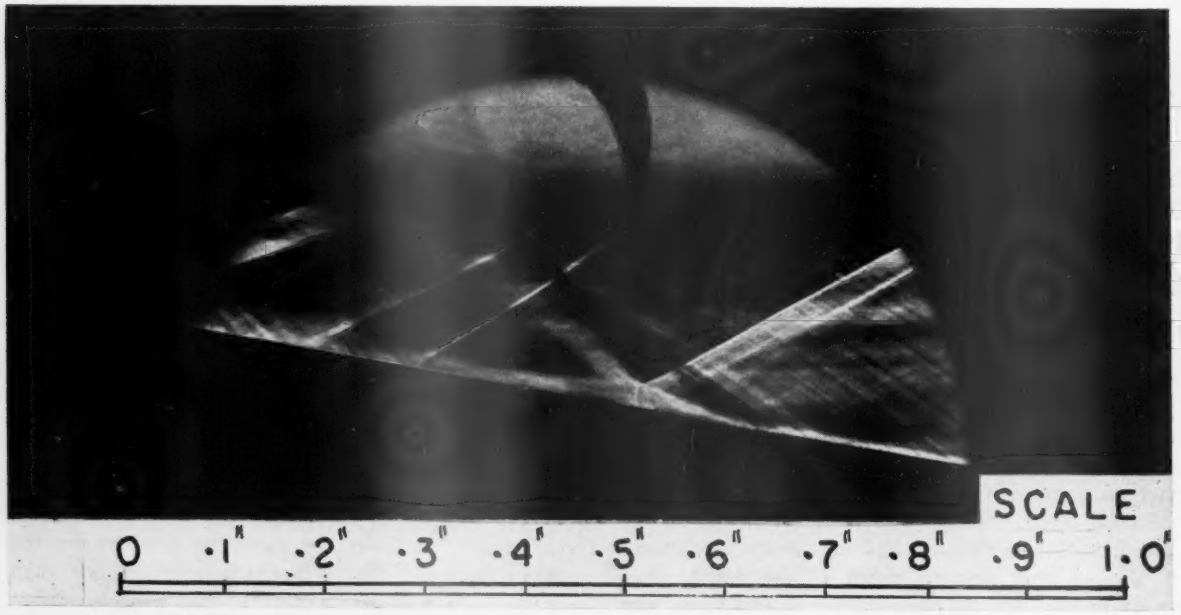

FIG. 5. 1/4 knife-edge schlieren of shock-wave boundary-layer interaction on 20° cone in nitrogen jet (magnification 6×).

A brief survey of the work that has been done by FAA to establish airworthiness standards for turbine aircraft used in United States civil operation.

Transport Aircraft Developments

Harold Hoekstra, FIAS
Federal Aviation Agency

THIS PAPER will be limited to transport category airplanes as defined in the Civil Air Regulations—that is, aircraft with a take-off weight generally over 12,500 lbs., having acceptable performance with one engine inoperative, and meeting other standards required for civil operation.

Piston-Powered Transports

Raymond and Hibbard in their classic papers [1, 2] on the Douglas and Lockheed transport series discussed how power increases, engineering refinements, and "stretch" produced the remarkably safe and efficient American transports that today carry the bulk of the world's passengers and cargo. However, at this time the Federal Aviation Agency has no applications in process for the approval of large piston engines. The increasing complexity, weight, and thermal problems of piston power appear to have brought to a close, at about 3,500 hp., the era of the engine that made powered flight possible.

Standards for Turbine Transports

A tremendous amount of work has been done to establish airworthiness standards. The FAA approach, starting in 1943, was one of general survey, fact finding, study, and development of proposed standards and their use as special conditions to supplement and, where necessary, replace the existing Civil Air Regulations. In all of this work, the fundamental principle of airworthiness has been observed—that is, *no single failure or probable combination of failures shall jeopardize the aircraft.*

This must be judiciously integrated with Murphy's Law that "anything that can happen, will happen," and the (M. G.) Beard amendment that "if it happens once, it will happen again."

Some of the major steps in the development of standards by the FAA follow:

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Mr. Hoekstra is Chief Project Officer—Transports, of the Federal Aviation Agency. During practically all of his 22 years in Government service, he has worked on the development and certification of transport aircraft. He is an aeronautical engineering graduate of the University of Michigan, holds a commercial pilot rating, and—in addition to his Fellowship in the IAS—is a member of *Aero/Space Engineering*'s Editorial Advisory Committee. He also is an Associate Fellow, RAeS, and a Member of SAE.

1946 Tentative Turbine Engine Test Standards.
1948 Civil Air Transport Evaluation and Development Board.
1949 Prototype Aircraft Report.
1950 Public Law 867—81st Congress (Prototype Law).
1951 Foreign Survey Group Report.
1952 Turbine Transports—CAA Policies issued. Certification procedure established (Letter, May 1). Turbine Transport Evaluation Team established (Dec. 4).
1953 Turbine Transports—Proposed CAA Policies (Yellow Book).
1954 Turbine Transports (Green Book).

From these steps and other work came major changes in the Civil Air Regulations, the first being Amendment 4b-2 adopted by the Civil Aeronautics Board on July 20, 1955.

Transports in Process of Certification

By law, an aircraft to be used in United States civil operation must first be type certificated by the FAA. U.S.-built transports must meet the provisions of Part 4b of the Civil Air Regulations. Foreign-built transports operated by U.S. owners are required by Part 10 to meet the provisions of Part 4b or the provisions of the airworthiness code of the country of origin plus such conditions as the FAA may impose to secure airworthiness equivalent to the U.S. code.

U.S. Manufacturers

As of February 1, 1959, there were twelve applications to the FAA by U.S. manufacturers for type certification of airplanes in the transport category. Eleven of these applications pertain to jet power; only one is a turboprop:

Boeing 707-200	Grumman 159
Boeing 707-300 & -400	Lockheed 329
Boeing 720	Lockheed 1329
Convair 22 (880)	Lockheed GL282A
Convair 30 (600)	McDonnell 119A
Douglas DC8 (Domestic and Intercontinental)	North American 246

Foreign Manufacturers

As of February 1, 1959, there were 13 applications by foreign manufacturers for FAA type certification of airplanes in the transport category. Three pertain to jet, five to turboprop, and five to piston power. These will be accepted as airworthy by the FAA upon certification of compliance with suitable standards by the particular foreign airworthiness agency involved:

United Kingdom	*France*
Armstrong Whitworth 650	Breguet Paris
de Havilland Comet 4 & 4A	Breguet 441
Handley Page Herald	Holste Super—Broussard
Hunting P107	Sud Caravelle
Scottish Aviation Pioneer	*Canada*
Vickers Vanguard	Canadair CL66A
Spain	de Havilland Caribou
Casa Madrid	

FAA-Approved Turbine Transports

Up to February 1, 1959, the FAA had approved the following three U.S.-built and four foreign turbine transport airplanes, using Parts 4b and 10 and special conditions:

U.S. Manufacturers	*Date of Certification*
Fairchild F-27	July 16, 1958
Lockheed Electra	August 22, 1958
Boeing 707-100	September 18, 1958
Foreign Manufacturers	
Vickers Viscount 745	November 1, 1955
Fokker Friendship	October 29, 1957
Bristol Britannia 305	April 10, 1958
Vickers Viscount 810	April 22, 1958

Operational Experience

Despite the intensive and exhaustive testing of new aircraft, the early operational experience of new types of transports is very closely watched by the operator, the manufacturer, and the Government. New to civil operation are the jet engine, the swept wing, the four-wheel main gear, high voltage alternating current systems, and others. The Boeing 707–100 is 52 per cent heavier than the Lockheed 1649 and 50 per cent faster than the Douglas DC7.

There are new problems and old ones in aggravated form, such as noise, smoke, runway limitations, clearance of obstacles, and the increased tempo of the flying, navigating, and communications duties. In general, operation has been good, although there have been difficulties. These cases are being intensively investigated, but final conclusions cannot be drawn at this time.

Transport Refinements

The usual engineering cycle of improvement is already under way. Two types of turbofan engines should be available soon. These engines should provide higher thrust, better fuel economy, and lower noise levels than their jet predecessors. They may present a bigger problem in obtaining suitable reverse thrust values.

The work of Whitcomb, Kuchemann, and others in aerodynamic refinement shows the way to delay the drag rise and step up cruise by several Mach points.

Structural changes will permit increasing the indicated airspeed or "q" limits for higher true speed at lower altitudes. This strengthening may also permit take-off with greater payloads, where ambient temperature limits do not prevent it.

Power settings, flap angles, and other parameters will be juggled to obtain maximum economy. Continuing experience in maintenance and operation will yield greater safety.

With the exception of specialized work on the glamorized supersonic transport, it appears that coming developments will be directed to improve safety, efficiency, and economy of the present types of transports with the operational speeds moving to higher and higher subsonic values.

The Supersonic Transport

The FAA has received no applications for certification of supersonic transports. Timing of their use will be dictated by competitive and political factors, as well as technical considerations. A recent (October, 1958) informal poll by the writer of some 38 key engineering and operational experts as to "When will we have a supersonic transport in U.S. scheduled passenger operation?" yielded an average date of May, 1970.

The FAA has done little actual work on the problems of supersonic aircraft airworthiness and operating rules. The following views, therefore, do not represent an agency position.

Sonic Boom

The Whitham equation[3] and NASA and military work point up the problem. The boom does not dissipate rapidly with distance, nor does it increase much with Mach Number. However, it does increase with cross-sectional area. The boom will be a major operational problem, and it will dictate the lower limit of altitude for supersonic flight.

General Design

According to recent studies,[4] the first U.S. supersonic civil transports will probably have a cruising speed of $2.5M$ to $3.0M$ or more; cruising altitudes will range from 50,000 to 80,000 ft. Some of the problem areas are listed as follows:

Structure

The operational speeds will establish temperature limits which in turn will dictate the nature of the structural materials. Substantiation of the structural integrity will require loading tests under high-tempera-

ture conditions. Load-time-temperature envelopes must be set up.

It may be necessary to use flight recorders in operation with temperature sensing of critical or significant areas.

Power Plants

Turbofan and straight jet engines with petroleum base fuels may be used up to about $M = 3.0$. Variable inlet geometry and variable nozzles may be necessary. A common inlet with variable geometry for a number of engines would be subject to very careful study because of the possibility that failure in the control mechanism would affect all engines. Cooling of engines and accessories with air having a stagnation temperature of 300° to 600°F. will introduce many problems.

Multiple engine damage may result from close proximity or clustering of engines. One engine failure or shutdown may significantly affect the airflow to the remaining engines.

Personnel Accommodations

Pressure differential will be determined principally by passenger comfort during descent. This may dictate a 3,000- to 5,000-ft. cabin altitude or a differential of 0.9 atmosphere.

Pressurization integrity is a must. The shell, glazing and windshields, ducts, clamps, pumps, valves, and other elements are vital. Refrigeration is also essential; the supersonic transport is an effective pressure cooker.

Despite the desire to keep transparent areas to a minimum for pressurization integrity in supersonic flight, the present side-by-side seating and flight deck arrangement should not be discarded without careful analysis. Crew teamwork is of paramount importance, and adequate visibility in subsonic flight is essential. Glass is fundamentally a good high-temperature, high-strength material. Watkins[5] has pointed out that progress is being made in the use of silicone interlayers for temperatures approaching 400°F. in place of the present vinyl plastics. Other work shows promise up to 900°F.

Pressure suits may be required for the crew, with pressure sealing doors or even an air lock between the flight deck and the passenger zone.

The Airport

Runway length and noise problems must be analyzed realistically and reasonable limits established. Public opinion trends indicate that the alternatives may be limits fixed by regulation.

Conclusions

For new transports, 1958 has seen the shift from piston to turbine power. Next will come a period of refinement to improve economy, flexibility, and reliability, with cruising speeds edging upward toward Mach 1.0. The supersonic civil transport picture is clearing, but a tremendous amount of work must be done to bring it into use in its specialized field.

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[1] Raymond, A. E., *DC-1, 2, 3, 4, 5, 6, 7, . . . n*, Preprint 507, SAE, New York, April, 1955.

[2] Hibbard, H. L., and Johnson, C. L., *The First Constellation Decade*, Preprint 506, SAE, New York, April, 1955.

[3] *Conference on Some Problems Related to Aircraft Operations*, NASA, Nov., 1958.

[4] *Supersonic Transports* (*Proceedings*), FF-20, IAS, New York, Jan., 1959.

[5] Watkins, *Glass as a Structural Member*, SAE, Detroit, Jan., 1959.

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The first hydro-fatigue test initiated in this country, with the C-130A Hercules, taught a great deal. However, fatigue testing of a pressure vessel is not adequate as a substitute for a fail safe structure.

Hydro-Fatigue Test of a Large Cargo Aircraft

J. E. York, MIAS

Lockheed Aircraft Corporation

A VIEW of the test setup is shown in Fig. 1. It consists of a steel tank 20 ft. high, 100 ft. long, and 20 ft. wide, and it holds 270,000 gal. of water. Additional details of setup and functional operation can be obtained from reference 1. The airplane was taken off the production line with a structurally complete fuselage, a center section of the wing, a stub horizontal tail, and a complete dorsal and vertical fin. It was necessary to have the dorsal and fin to structurally complete the fuselage.

The airplane is submerged in the tank for the test. The fuselage and the tank are simultaneously filled with water. Additional 500 gal. of water are pumped into the fuselage to achieve the desired pressurization to 7.5 psi. As fuselage pressure rises, hydraulic jacks lift the wing at four load points, simulating wing lift. Bonded straps and internal loading beams hold down the airplane fuselage, simulating the pull of gravity. A single hydraulic jack applies the horizontal tail load. Thus, the submerged airplane experiences simulated high altitude flights up to 35,000 ft.

Loading Spectrum and Derivation

For the purpose of investigating the loadings to be applied during the test, it was considered that the loads should originate at take-off, extend through a selected representative flight, and terminate with the landing loads. Accordingly, load spectra were estimated for a representative C-130A flight of 3 hours (906 miles). The selected flight itself consisted of take-off, climb to 20,000 ft., cruise, descent, and landing.

The in-flight portion of the flight was considered to be composed of maneuver and gust loadings. Transport, gust and maneuver data, collected and summarized by the NACA[2] were employed in establishing the expected flight loading gust and maneuver portion of the test spectrum. Also, B-17 data analyzed by The Glenn L. Martin Company[3] were used in deriving the maneuver portion of the spectrum.

Although maneuver data on other low load factor military aircraft were available, the type of mission involved, in most cases, precluded comparison with the C-130A. Bomber data, such as that for the B-17, appeared to approximate more closely the C-130A mission. However, study of the data indicated that the C-130A would, in military service, experience more maneuvers per flight than a commercial transport and yet would not be subject to the possible relatively violent maneuvers experienced by bombers at or near a target area. For these reasons, the maneuver spectrum selected was taken as an approximation between commercial data and B-17 data. The resulting spectrum, however, did not deviate materially from the two spectra.

J. E. York was graduated in 1937 from Georgia Institute of Technology with a B.S. degree in Aeronautical Engineering and for the ensuing 3 years was on The Martin Company structural engineering staff. In 1940, he joined Lockheed (Burbank) as Structures Engineer, a post he held while also acting as Consultant for three Los Angeles firms until 1952. In that year, he was promoted to Project Structural Engineer in the Georgia Division.

Following computation of the gust and maneuver spectra, these data were combined to produce the composite spectrum.

On the assumption that the number of side gusts encountered on a given flight would equal the number of vertical gusts, the gust spectrum previously calculated on an incremented load factor basis was converted into a frequency vs. gust velocity spectrum. From these data, it was then possible to compute the resulting vertical tail loads and, ultimately, the damage due to side gusts. These calculations are discussed in more detail in the next section. The landing load to be applied was based on a landing weight of 89,400 lbs. and a sinking speed of 3 ft./sec. The sinking speed was assumed to be an average value based on statistical data sampled during the Berlin Airlift operation.

Determination of Applied Loads

For the purpose of determining the applied flight and ground loads, and the resulting damage, a time weighted average of weight, speed, and altitude were used. In accessing gust effects, it was assumed that the airplane

was immersed in the gust so that the tail was the only portion of the airplane outside the gust. This assumption was conservative for analysis of the aftbody loading (the forebody loadings were unaffected thereby), in that an upward acting gust would reduce the normal down loads on the horizontal tail, although the inertia loads would be increased. For downward acting gusts, the horizontal tail loads would, of course, increase but the inertia loads would decrease. Hence, by maintaining the level flight pregust loads on the tail, the highest fuselage loading was obtained.

The skin splice at fuselage station 657 was determined to be the most critical element from a fatigue damage point of view for the aftbody for longitudinal stresses and was used to determine the critical loading for this part of the specimen. The material at this station is 75ST Alclad with the skin dimpled. For the particular rivet spacing, a S-N curve was obtained from NACA Report.[4] The stresses at this splice were computed for the total load factors up to 3.5 and the damage (Miner's cumulative damage theory) for the applied spectrum was computed. The stress was then computed that would produce the same damage for a single application of load as the damage for the entire spectrum per flight. The corresponding load was translated to a Δn to be applied to the 1g load plus pressure. This Δn was found to be approximately 0.70g. A similar analysis was performed on the most critical area of the forebody, again a skin splice. The Δn for equivalent fatigue damage was 0.72g.

Analysis of the effects of landing loads and side loads on the vertical tail indicated, first, that very little structure was affected, and, second, that most of the fuselage structure affected was much more critical for repeated pressurization and other loadings than for the landing and vertical tail loadings. Exceptions to this were the areas immediately adjacent to the landing gear and vertical tail connections. The landing gear connections were planned to be covered in separate tests. The vertical tail connections were not included for test simplicity. (These are to be proven in another series of tests to be conducted in the future.) Consequently, the test loads for the fatigue test were

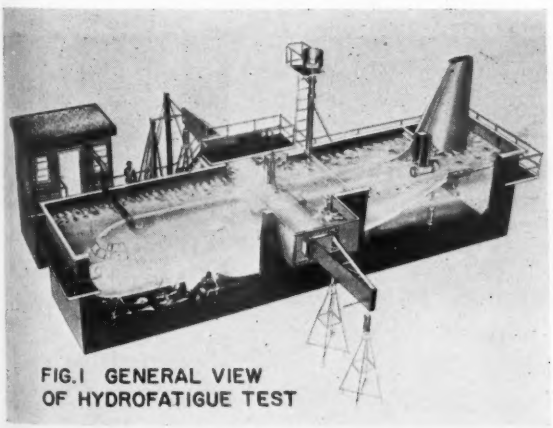
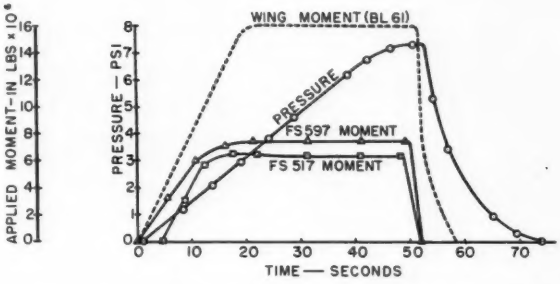


FIG. 1 GENERAL VIEW OF HYDROFATIGUE TEST

C-130 FUSELAGE FATIGUE TEST
TYPICAL CYCLE OF PRESSURE AND APPLIED BENDING MOMENT

FIG. 2



established to be 7.5 psi pressure at 1g level flight plus an increment of load corresponding to $\Delta n = 0.72g$. The Δn corresponds to a gust velocity of 22.5 ft./sec.

Actually, much of the analysis and reasoning employed in selecting the test loads was somewhat academic since damage due to pressurization predominated in all cases, especially that due to "hoop tension." For the longitudinal stresses, the difference in damage between the loading of 1g at pressure and 1g + pressure + Δn is small. The fact that pressurization loads would cause most failures was confirmed by the test results.

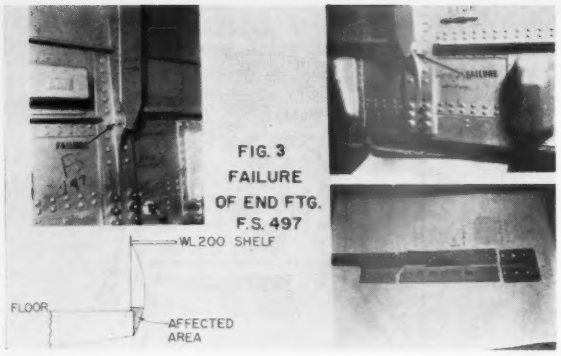
Based on negotiation with the Air Materiel Command, the number of test cycles was set at 20,000. This corresponds to approximately 60,000 operational hours under the assumptions previously outlined.

The load cycle as applied to the test airplane is shown in Fig. 2. A load cycle consists of applying the proper wing and fuselage moments and pressure following the time history shown. It can be noted that the moments build up first, followed closely by the pressure. The load and pressure magnitudes were controlled quite accurately; the actual shape of the build-up and delay curves was a matter of convenience. The cycle took 72 sec. at first but was finally speeded up to 1 min.

Abstract of Test

The hydro-fatigue test on the C-130A was started in September, 1956, and was completed to 20,000 cycles in August, 1958. Fixes for failures were incorporated as failures occurred. At 10,000 cycles, the most extensive modification of the test fuselage was made to incorporate fail safe and other improvements indicated as desirable by the test and independent studies. The structure was made fail safe and thereby considerably more fatigue resistant. After the fail safe improvements were incorporated, the cycling program progressed more rapidly and repairs were minimized as the failures were confined to local areas. Many things were learned from the test that should be most useful in the future, both in C-130 airplane improvement and new aircraft type designs and improved testing techniques. Here are some of the observations. Pictures and more details of these will follow.

(1) Small nuisance cracks can be expected that do not



grow in size. There were twelve such cracks that appeared in the first inspection period (approximately 200 cycles) and did not propagate during the remainder of the test. The most likely cause of such cracks is inadvertent damage during assembly.

(2) All fuselage fatigue failures are considered to be the result of pressure loads. Consequently, the simple, one stress level spectrum is considered justified. This finding does not correspond to results of the Comet test in that the Comet test indicated that the other than pressure loads were more significant than originally supposed.[5]

(3) A remarkably low scatter factor has been experienced. In analyzing 32 failures, repeated either with new parts or other identical parts on opposite sides of the ship, the average scatter factor is 1.4. This was an unexpected result since we were used to factors from element tests as large as 9:1, as experienced by others.[6]

(4) Magnesium skins deteriorated prematurely. Early disintegration of magnesium skin was due to environment, laboratory tests have indicated (see following section). Airplane service records do not indicate any such problem. Aluminum and steel parts showed no signs of being affected by the test environment.

(5) *Component fatigue testing can be misleading.* Some components which had been bench fatigue tested to an indicated satisfactory fatigue life, failed early in the airplane test. In an assembly, there are eccentricities and redundancies that can cause premature failures.

(6) The incidence rate of minor failures did not increase with increasing test cycles. The rate was constant during the entire program.

(7) Major structure failures started later in the program and continued at a constant rate.

(8) Flat panels in pressurized skins are real problem areas due to pillowing of skin between rivet lines and eventual cracking along the rivet line.

(9) End fixity of beams and frames and the corresponding end moments were generally larger than anticipated, causing earlier than anticipated failures at ends of some beams and frames.

(10) Skin divers and underwater television proved to be of little value. Areas that were being watched did not get worse rapidly enough to be critical until other areas failed. These methods were abandoned in favor of more frequent draining of the test tank to enable thorough inspections.

(11) The review of the failures indicated that exist-fail safe methods of analysis are reliable.[7]

(12) The test has indicated areas where aircraft serviceability and safety can be improved and how and what parts should be inspected.

Some Failures and Their Evaluation

Magnesium Skin Failure

This application of the magnesium skin was nonstructural but it picked up loads due to fuselage deflection. The magnesium skin was replaced with aluminum after numerous failures which were eventually ruled environmental even though the pH of the water was controlled. Electron microscopic studies indicated galvanic corrosion occurred between a precipitated iron aluminum compound and magnesium grain materials.

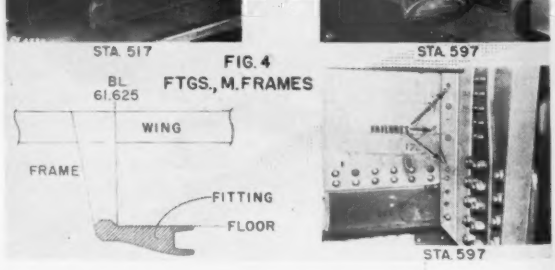
Crew Door Hook Failure

The aft of the two crew door retaining hooks failed at 4,071 cycles. Bench fatigue tests had been made on these hooks with the minimum failure of four specimens at the equivalent of 25,000 pressure cycles. It is believed that in the airplane there are eccentricities and the load between the hooks is not equal, as was assumed in the component test. The eyebolt in which the hooks engage was increased from 1/2 in. to 5/8 in. diameter to increase fatigue life. This was an example of fail safe design. Several single hook or eye failures occurred with only gradual loss of pressure.

Failure of Pressurized Flat Panels

Nose Gear Wheel Well

A flat panel, $5^1/_2$ in. by 8 in., of 0.025 75ST Alclad forming part of the pressure bulkhead located in this area, failed at 3,230 cycles. The attaching rivets were in tension. This was corrected by adding a $1^1/_4$ in. by 0.032 in. strap to prevent pillowing of skin at the rivet line.



Forebody Skin Failure

This flat panel in the forebody failed simultaneously on left and right sides and was detected by an increase in pressurization time. The panel was $8^1/_2$ in. by 24 in. of 0.032 75ST Alclad. To improve this condition, intercostals were added at 7 in. spacing on the left side without changing the skin. On the right side, the skin was increased to 0.051 24ST Alclad. There was no trouble on either side after the repair.

Failure of End Fittings due to Fixed End Moments

The Figs. 3 and 4 show fitting failures due to high fixed end moments. These failures were found during regular inspection.

End Fitting Fuselage Station 497

This fitting (Fig. 3) is part of a beam on the flat portion of the fuselage which distributes the pressure load to the floor and horizontal shelf located about 50 in. above the floor. The fitting failed as shown. These were replaced with redesigned stronger fittings.

Fitting at Main Frames

This (Fig. 4) is a picture of the main fuselage frames (vertical) which tie to the front and rear wing spars. These heavy forgings failed due to unexpectedly high fixed end moments at the floor frame connection. A 3/8 in. 24ST plate was added to each fitting for reinforcement.

Pilot Floor Fittings

This fitting is the tie between fuselage frames and the pilots' floor. These fittings made of extrusions failed due to end high fixity. A heavier extrusion was tried and it also failed. Then a bent-up angle was tried. This deflected freely and has worked satisfactorily ever since.

Aft Cargo Door Skin Failure at Bleed Valve Hole

(Fig. 5). At 3,234 cycles, the skin and doubler developed a 7 in. crack at the emergency bleed valve which extended forward to stop at the skin splice at the frame. It was assumed that the thick rubber seal between the bleed valve and the skin caused the failure because the skin had bowed out between the screws,

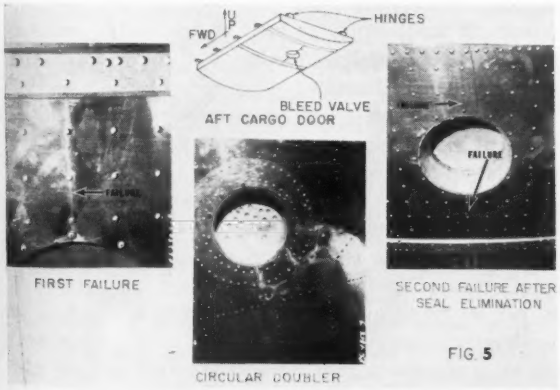


FIG. 5

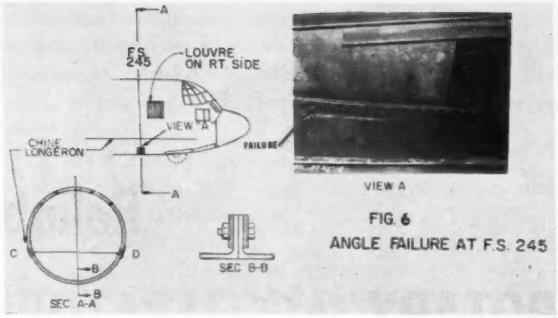


FIG. 6
ANGLE FAILURE AT F.S. 245

causing the skin to breathe when pressure was applied. The skin was replaced and the rubber seal was omitted. This did not solve the problem as a second failure occurred, indicating that the rubber seal was only partially responsible. This time the failure progressed forward and aft through the skin and doubler, as shown in the right photograph. The structure was fail safe due to narrow sheet which acted as a crack stopper. The frames were sufficiently strong to take the additional load dumped by the failed skin. A 0.080 in. ring was added around the hole for reinforcement and was intact at the program end.

Failure at F.S. 245 at 5,480 Cycles

(Fig. 6). This failure occurred at the match angle splice between the forward fuselage and the mid-fuselage. This is a common type of splice and should be of general interest.

The failure occurred in the bolt line attachment due to flexing of the angle, as shown in view "A." The failure ran along the angle from C to D. Fortunately, the structure was fail safe due to the strength of longerons C-D which stopped the failure. Our fix for this failure consists of adding straps to the angles as shown in section B-B.

Conclusion

There is a lot that can be learned and much benefit can be derived from a hydro-fatigue test. However, in our opinion, it is not an adequate substitute for a fail safe structure. Fail safe design and testing should come *first* as a must, while the hydro-fatigue test should be a complimentary program where practicable. If there are a sufficient number of airplanes in the program, a hydro-fatigue type test should be economically sound.

The C-130A was designed, starting in 1952, when the fail safe concept was not advanced. The structure was not intentionally designed with fail safety as a prime consideration. Prior to this time, highly pressurized, large volume aircraft were not flying or had not experienced serious explosive failures. Starting with the Comet disaster in 1954 and the development of higher flying transports, the fail safe philosophy has become a most important factor. The findings from our hydro-fatigue test agree with other investigations[8] and have

(*Continued on page 56*)

Environmental test equipment is now available for many purposes but the rotary accelerator remains the only machine capable of producing a constant acceleration over a sustained interval.

Reliability Testing Using ROTARY ACCELERATORS

Martin L. Aronow

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A graduate of Drexel Institute in Philadelphia, the author served as a metallurgist with the Manhattan Project at Los Alamos during World War II. Later he went to the Allied Chemical & Dye Corporation as a project engineer. For the past 9 years, Mr. Aronow has worked with the Schaevitz companies in Pennsauken, N.J., where he is now Director of Engineering. During this time, he has been responsible for engineering, design, and production of rotary accelerators, linear and rotary variable differential transformers, accelerometers, pressure transducers, and other products.

THE HIGH COST of complex modern aircraft and guided missiles accentuates the need for improved techniques for environmental testing in the laboratory. Field tests are expensive and it is difficult to obtain data on the manner of malfunction in the event of failure.

Historically, only a short time has elapsed since the days when the only type of environmental testing available was by actual use. As an example—if one wanted to know how a particular piece of equipment would perform in tropical environments, the only solution was to take it on a safari in the African jungle or put it to use on some tropical island. This method has obvious advantages when a winter vacation is indicated but its shortcomings are evident when the information desired pertains to the performance of the same equipment under arctic conditions, yet such a test is often extremely important. Operational tests conducted during the current polar expeditions for the International Geophysical Year are an excellent example.

Environmental test equipment is now available for many purposes. Examples are: high and low temperature; sand and dust; salt spray; altitude; underwater; and acceleration tests. A number of types of acceleration testers have been devised and are in wide use. These include shock machines, vibrators, drop testers, rocket sleds, and rotary accelerators.

Of the devices mentioned, only rotary accelerators and rocket sleds are capable of subjecting a test object to a constant and sustained acceleration. In the case of the rocket sled, if the test object is subjected to an acceleration of considerable magnitude, it soon reaches a linear velocity that is so great that the tests become impractical. This leaves the rotary accelerator as the only practical environmental test machine capable of producing a constant acceleration over a sustained interval.

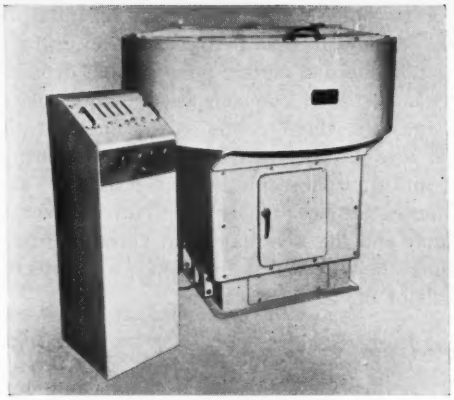
The purpose of this paper is to trace the development of the rotary accelerator as an environmental test and/or instrument calibration device, and to indicate to the reader the manner in which this type of machine can assist him in producing a better and more reliable product, or reduce the time and cost of developing new components or system elements. It is intended to indicate the position of the rotary accelerator in the field of environmental testing and to discuss briefly the manner in which this type of machine is designed and used.

The rotary accelerator is basically a centrifuge with an accurately controlled and measured angular velocity, having a rotating table or arm on which the equipment under test may be mounted. Sets of slip rings and brushes, to supply power to the equipment being tested and to read the instrument outputs, complete the basic machine. Other components and auxiliary equipment are used for purposes of convenience or to extend the usefulness of the accelerator.

In addition to its function as an environmental test device, the rotary accelerator serves as an important means of calibrating seismic instruments, such as accelerometers, under constant and very accurately known radial acceleration.

The acceleration of any point on a body rotating at constant velocity about an axis may be expressed by the relationship: $a = RW^2$.

Where R is the radius from the axis of rotation to the point in question and W is the angular velocity in radians per sec., a is the acceleration. If the unit of length used is the foot, the acceleration is expressed in ft. per sec.^{2} As a matter of convenience, the unit of acceleration often used is the G. This simply designates the force of gravity, and the accelerations may then be



Typical rotary accelerator and control console.

expressed as multiples of G: $G = RW^2/32.2$.

If the units of radius are changed to inches and the angular velocity to r.p.m., the equation takes the form: $G = 2.84 \times 10^{-5} rn^2$; r = radius, in.; n = r.p.m.

Construction

The mechanical design of the rotary accelerator is intended to combine the various desired operational features in an optimum fashion, while retaining safety, reliability, and convenience in the overall machine. To that end, much work has been done to determine the general requirements in the field of acceleration testing and to develop standard machines that meet these requirements. This results in a saving in time and cost for the user and permits the manufacturer to produce these machines in anticipation of sales. However, not all requirements can be filled in this manner. Therefore, many machines have been designed so that they may be produced as convenient subassemblies which may be selectively combined to meet particular requirements. Finally, there are still other requirements that can be met only by custom-built machines. In these instances, specifications must be complete, detailed, and specific, and sufficient time allowed for the design as well as the construction of such a machine. Some of the major design features are discussed briefly.

Speed Control

There are a great many possible types of drive that should be considered in selecting the proper one for a rotary accelerator application. Ideally, a rotary accelerator requires a drive that will vary with perfect smoothness from zero to maximum speed, maintaining any set speed in this range precisely and for an infinite time. While this drive may be easily described, the cost of attaining such an ideal condition is usually prohibitive. Therefore, in most instances, the user should base his selection of a drive on his own particular problem. In general, environmental tests to prove that a particular test object will withstand a specified minimum acceleration do not require great accuracy in the drive. Here the choice should be made on the basis of convenience in testing. On the other hand, calibration of accelerometers or other acceleration-sensitive devices, such as acceleration time fuses or gyroscopes, requires ease of setting and speed stability of the highest order. Some of the commonly used types of drives are:

(1) Variable pitch pulleys and V-belts.
(2) Mechanical gear drive with discrete steps, such as auto transmissions.
(3) Hydraulic drives:
    (a) Positive displacement type.
    (b) Variable displacement type.
    (c) Torque converter.
(4) Hardened roller type.
(5) Ball and disc integrators.
(6) Electrical drives:
    (a) D-c motor with potentiometer field control.
    (b) Motor generator type.
    (c) Thyratron controlled type.
    (d) Combination type.
    (e) Synchronous motor with controlled frequency.

These and other types of variable speed drives are referred to in articles on adjustable speed drives by Rogers, Spector, and Carlson, published in the magazine *Machine Design* during 1957.

Power

The power required to drive a rotary accelerator may be divided into three parts: to overcome friction and windage in the drive and spindle; for acceleration or deceleration; and to overcome windage of the rotating arm and test object. Mechanical friction is generally proportional to speed and a relatively small fraction of the total. It may be readily estimated by well-known empirical methods or measured in an existing machine by removing the rotating arm and determining the power input at a number of constant speeds.

Power required for acceleration and deceleration is readily determined by computation if the rotating arm and the test object are both geometric objects for which the moment of inertia may be computed. If they approximate a simple geometric object, a sufficiently accurate computation is easily managed.

Windage losses by the rotating arm and test object represent the largest portion of power consumed in many accelerators and vary as a high exponent of the angular velocity. They are greatly affected by the aerodynamic form of the rotating parts. Approximations made by assuming a flat plate whose plane is perpendicular to the direction of rotation are not sufficiently accurate. Neither does the assumption that the rotating arm test specimens represent a flat-bladed fan yield a useful approximation. The safety guard is also a major factor in the amount of power consumed, and its smoothness and closeness to the ends of the rotating arm often affect the power requirement. Actually, the only way to obtain even a reasonably accurate estimate of the power required to overcome windage is to interpolate from experience or from measurements obtained on similar machines (see Fig. 1).

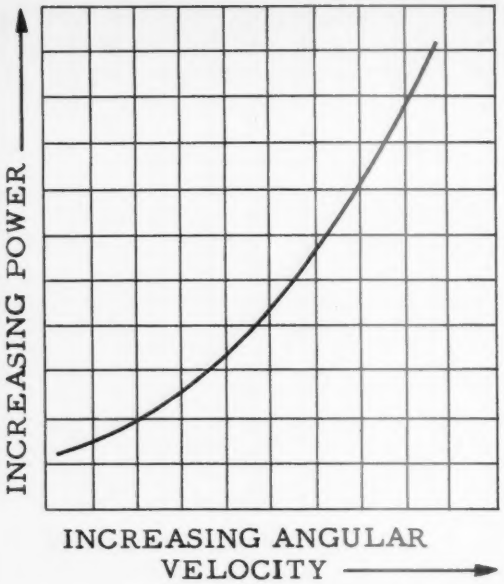


FIG. 1. Curves showing how power varies with speed.

Windage should be kept at a minimum consistent with the conditions of the test. Neglect of this factor can result in excessive power requirements and in air buffeting with consequent variations in speed during a revolution.

Speed Measurement

There are a great many techniques available for measuring the angular velocity of a rotary accelerator. Where convenience and rapid readings are desirable but great accuracy is not required, a simple method is to use a d-c tachometer with a voltmeter that reads its output. Since the output of a d-c generator varies almost directly with speed, a reasonably linear calibration curve is produced.

Pulse Generator

Another method of speed measuring is by the use of a pulse generator, consisting of a permanent magnet type pickup and a toothed wheel that rotates at the spindle speed (or proportional to it) and produces one voltage pulse as each tooth passes the magnet. This device lends itself to a number of convenient measuring techniques. Since the output voltage is again proportional to the velocity, the speed measuring method used in the previous technique is also usable in this case. However, there are some additional advantages. The pulses may be counted by a suitably accurate electronic counter and produce a digital readout. Great accuracy is readily obtainable since electronic counters are notably able to measure time intervals and count pulses with precision, usually ± 1 count.

Stroboscopic Light

A basically different technique for accurately measuring speed involves stroboscopic light. Marks on the rotating arm may be stopped by a light from a strobotach or stroboflash, and the speed accurately determined. Although this permits the accurate determination of speed at certain points, it has definite limitations in terms of convenience and interpolation of speed between these points. A refinement of this method uses the electrical pulse generator mentioned earlier and a stroboscopic frequency meter. This arrangement combines excellent accuracy with continuity in reading and the advantage that variation from a set speed may be observed in magnitude and direction on the dials of the frequency meter.

Counter-Timer

Still another method that is simple and direct is the use of a mechanically connected revolution counter and an electromechanical timer. The disadvantages of this method are that it measures over a discrete and relatively long interval of time, and the clutching (or declutching) time appears as an error in the reading.

Many other methods of speed measurement, such as a-c tachometers, time interval meters, etc., will occur to the reader since those mentioned by no means constitute a complete list, but, rather, a listing of methods in common use at this time. Many of the preceding techniques also lend themselves to automatic reading and recording.

Accuracy

In calibrating instruments, the accuracy to which the acceleration is known depends upon the accuracy to which the angular velocity and the radius are measured. Methods of determining angular velocity were discussed in the preceding paragraphs. In addition to actual measurement, the accuracy to which the effective radius is known depends upon bearing eccentricity, location of the center of gravity of the test object, temperature changes, and other variables. The total acceleration may be expressed as follows:

Where W = angular velocity
e_w = error in angular velocity
r = radius
e_r = error in radius
e_a = error in acceleration

$$\% \text{ error } e_a = \{[(r + e_r)(W + e_w)^2 - rW^2]/rW^2\} \times 100$$

An analysis of the errors will show that a given percentage of error in measuring angular velocity will produce about twice as much error in the final result as an equal percentage of error in determining the radius. It will also show that there is no great value in measuring one variable with great precision unless the other variable is determined with the same order of accuracy.

Braking

Rotary accelerators can successfully utilize almost every type of braking that is ordinarily used on mechanical equipment. Examples that come to mind are mechanical brakes, friction brakes, hydraulic

brakes, dynamic regenerative electrical, and hydraulic servo-controlled brakes. If a drive using a d-c motor is selected, dynamic braking is easily applied at very little cost. All that is required is a contactor and a resistor to consume the kinetic energy of the system. The amount of braking applied is readily adjustable by the ohmic value of the resistor placed in series with the armature. Mechanical braking may be as simple as grasping the rotating arm or disc in the operator's hand as it slows down, and it can have any desired degree of complexity from there on. A simple method is a brake band manually applied around the spindle. Hydraulic brakes of the type ordinarily used to stop industrial equipment are also applicable. Where programing of angular velocity vs. time is practiced, the braking becomes a very important feature, and here consideration should be given to the use of servo-controlled brakes using either an electrical or hydraulic servo system.

Balancing

A question often asked is how accurately the rotating element of an accelerator must be balanced to assure freedom from vibration and produce the desired degree of accuracy in testing. This is a question that the user must answer for himself for each particular test. Just as much care is necessary to avoid too much accuracy in balancing as too little of it because much time and effort can be spent in obtaining an accuracy of balance unnecessary for the test in question. As a general rule, a slow speed and rigid machine will permit considerable amounts of both static and dynamic unbalance without any ill effects on the machine or errors in testing. As speed is increased, a reasonably good static balance may be required. For high speeds, dynamic as well as static balance should be considered, and the degree of unbalance permissible should be determined by experience. In the use of very high-speed high G tests where stresses become critical, balancing methods, such as those employed for high-speed grinders and ultra-centrifuges, must be considered.

Connections to External Equipment

Important items in the design of an accelerator for the calibration or test of electrical equipment are the slip rings necessary to supply power and transmit information from the test specimen. The power slip rings should permit the introduction of as many voltage, frequency, and current levels as may be required. In addition, the instrumentation slip rings should transmit the information with the least possible amount of cross-talk, noise, or distortion. To that end, materials for the rings, brushes, leads, and insulators must be selected and applied with great care and appreciation of the particular measurements to be made. It is difficult, almost impossible, to design one particular type of slip ring for all conditions. But suitable slip rings can be made for almost any individual condition expected.

The items most often tested and calibrated are electromechanical devices. In order to operate such devices while subjecting them to acceleration forces, it is often necessary to connect them to pneumatic, hydraulic, and electric sources of power and instrumentation. To accomplish this, a wide variety of slip rings are required for power, instrumentation, high voltages, and frequencies from the d-c to the RF range. For higher frequencies—i.e., UHF and microwave—transmitters are often mounted on the rotating arm with stationary receivers to pick up the intelligence, or the reverse.

Pressure lines for high-and-low pressure air, vacuum, hydraulic fluid, corrosive fluids, etc., have also been devised. Various combinations of slip rings and lines are frequently installed in a single machine to meet special requirements.

Optical Systems

As soon as the first rotary accelerators came into use, the question arose of visually observing the object being tested. At slow speeds, this visual observation can be accomplished without special equipment, and at speeds of 600 r.p.m. and over stroboscopic stopping permits reasonably critical observation of the test object. This leaves an intermediate region in which neither direct observation nor proper stroboscopic observation may be made, and it is for this purpose that optical viewing systems have been devised. These systems generally consist of an objective lens assembly which has the property of stopping the image, regardless of the speed of the table rotation, and the necessary telescope so that the rotating object may be conveniently observed. An optical system of this type provides continuous viewing of the test object as opposed to the intermittent view provided by a stroboscopic device.

Programing

Setting up a series of test conditions that can be achieved by the machine, without operator attention or control, is especially desirable where repetitive tests are to be performed in production situations. Broadly speaking, this programing is of two types.

An example of the first type involves the setting up of a series of fixed speeds that the machine could find on push button command. These speeds may be set with considerable accuracy and result in a very convenient method for calibrating a device such as an accelerometer. A timer can be set to operate the switches, thus avoiding the attention of an operator even for pushing the buttons. The operator would then be free to record data. This process can be further mechanized by the use of voltage-sensitive relays to determine when the accelerator has reached a preset speed, and cause the calibration data to be taken automatically. An approach of this type would permit the calibration of accelerometers to be made rapidly and accurately, and also provide an automatic record with little or no effort on the part of the test technician.

The only prerequisite for such a method is sufficient repetition in the test requirement to justify the effort and expenditure required for the initial setup.

A more difficult type of programing is one which requires subjecting the test unit to a predetermined variation in acceleration with time. An example of this type of requirement is an acceleration time device for the environmental test of an object that must perform adequately in the rapidly varying acceleration environment of a missile. This type of programing is difficult to accomplish because the rotating element of the accelerator must often be subjected to enormous accelerating and braking forces to comply with the requirements of an acceleration time program curve.

Size Ranges

Size ranges of rotary accelerators vary from quite small, almost "portable" machines to machines capable of testing an entire electromechanical assembly, a complete missile, etc. The largest machines may occupy a building of considerable size. Neither end of the ultimate size range has yet been approached, and both larger and smaller accelerators are being considered every day. As a general rule, small machines are preferred for use as calibration devices for accelerometers, gyros, etc., and large machines for environmental tests of completed assemblies. In selecting a machine, the purposes for which it is to be used must be given careful consideration, and a machine of adequate but not excessive size should be selected since the speed and convenience of running tests is directly dependent upon the size of the machine. As a result, where test objects of widely varying sizes are to be tested, it is often more economical to consider using more than one machine rather than to attempt to custom-build all of the desired features into one test stand.

In selecting the size of machine for a given project, careful consideration must be given to the *G*-gradient across the test object. From consideration of the most elementary mechanics, it can be seen that the acceleration of the test object at any point is directly proportional to the distance from that point to the center of the machine, and if the test object is large, it is obvious that a comparatively large difference in radius may exist between the nearest and farthest point and the center. For example, in a 1 ft. cube of homogeneous nature with a radius of 3 ft. from the center of rotation to the center of gravity, the *G* forces at the nearest point will be approximately 16 per cent less than those at the center of gravity, and those at the farthest point approximately 16 per cent more. Now suppose the distance between the center of rotation and the center of gravity is reduced to 2 ft., then the variation in *G* between the nearest point and the center of gravity is 25 per cent. On the other hand, if the distance to the center of gravity is increased, the *G*-gradient across the test object is reduced.

Gradient is not ordinarily a serious consideration when environmental tests are to be run because it is simply necessary to make sure that a certain minimum value is exceeded. This can be managed either by mounting the test object in more than one position or by subjecting the point nearest the center to the minimum *G*, and the other points to substantially more than the minimum. On the other hand, where calibration is to be accomplished, *G*-gradient is a matter of the utmost importance. There is usually one point in the object or instrument that is sensitive to acceleration. This point should be determined and used as the point which receives the nominal acceleration. In this manner, the problems of *G*-gradient can often be avoided. However, there are numerous tests in which minimizing the *G*-gradient is of importance, and in such cases an accelerator having the largest possible radius of rotating arm that is compatible with the other requirements of the machine should be selected.

New Developments

In addition to the more usual requirements, there are occasional requirements for machines to subject a test object to several motions at once. For example, a sinusoidal or harmonic variation in *G* can be superimposed on a constant *G* by placing the test object on a rotating platform at the end of a rotating arm.

Machines have been devised to simulate roll, pitch, and yaw for the testing of equipment to be used on shipboard and aircraft. A rotary accelerator with its axis in the horizontal position applies an acceleration force that varies by the amount of plus or minus one *G* because of the effect of the gravitational field.

High Speed

Recent demands for the testing of small components, such as transistors and relays for use on missile and high-performance aircraft, have added the requirement that these items withstand being subjected to thousands of *G*'s, and machines to perform these tests conveniently are being devised. Here the only limit appears to be the development of a rotating disc material that will withstand the speed without shattering under the centrifugal stresses. Where the speeds become very high, a problem of noise in slip rings develops due to brush bounce and the voltages generated by rotating conductors (the leads) in the earth's magnetic field.

Universal Environmental Machine

An ideal environmental test system would be one that permitted the subjecting of a wide variety of equipment to the extreme of all environmental factors simultaneously or in any combination, with full control of each factor. This would result in obtaining information that would be superior to that contained in use tests, as well as much more realistic than that obtained by subjecting the equipment to one single environmental condition at a time. Combinations of equipment for this purpose have been devised and are continuously being improved, and in the near future may be available in every environmental laboratory.

The new turbojet engines require the additional thrust of a water-injection system at take-off. This creates a great need for deionized water systems at our airports.

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Charles F. Raines

Rohm & Haas Company

A NEW and different ground service facility is becoming necessary at many of the larger municipal airports. This is the production of an adequate supply of high-quality water for the water-injection systems of the new turbojet engines. Already a number of USAF fields have installed deionized or mineral-free water production facilities to service several types of military aircraft. Now, as the turbojet engine is being adapted for commercial aircraft, the availability of deionized water will become a requisite for many more airports.

The need for such deionized water systems stems from the development of new engines which require the additional thrust of a water-injection system at take-off, and involves the cooling effect of the water to keep engine thrust at the level achieved in standard 60°F. air, and, in some instances, to increase thrust on a standard day.

Increased engine thrust at take-off permits the plane to carry a full load and to become airborne in the shortest runway distance. The introduction of a water-injection system into such an engine as the Pratt & Whitney J-57 produces a greatly increased thrust. With water-injection, each engine develops 13,000 lbs. of thrust, while the engine running dry develops only 11,200 lbs. of thrust on a standard day. This represents an increase of nearly 14 per cent thrust with water-injection.

Water-injection helps to offset the "hot day effect," in which the thrust of a dry jet engine decreases rapidly as the outside temperature increases. The vaporizing water cools the inlet air and permits it to deliver a constant thrust comparable to the thrust in 60°F. air.

Although the consumption rate of deionized water during a wet take-off for a typical engine is equivalent to 40,000 lbs. per hour, per engine, the water-injection is only in operation for a short time at take-off. A plane like the Douglas DC-8 or the Boeing 707, which is equipped with four of these J-57 engines, would require about 6,000 lbs. of water or up to 750 gal. per take-off.

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Since aircraft may fly in temperature zones below the freezing point of water, it is important that any water remaining in the tanks after take-off be drained from the plane. Antifreeze solutions are not generally used because of their corrosive effects and other complications they add to combustion and control problems.

Clearly, every airport engaged in servicing these planes must provide deionized water in adequate quantities. A few water deionizing units have already been installed and are servicing several types of engines. Deionized water is being prepared, mixed with methyl alcohol, for the injection system in the Rolls Royce Dart RDa7-MK525 on the Continental Air Lines' Viscount-810s (Fig. 1).

It may be used effectively in the Pratt & Whitney PT2G turbowasp now powering the Douglas YC-133 cargo transport, the Lockheed C-121F, and the Boeing C-97J. It is thought that the majority of present and future turbojet engines will require deionized water for take-off. While specifications on some proposed turbofan engines may not require water-injection, it is possible at this time that this provision may be included in future turbofan proposals.

Water Purity

Experiments have shown that while ordinary tap water performs in these engines in the same fashion as deionized water, tap water has many impurities which cannot be tolerated. These impurities are in the form of electrically charged particles in solution (ions). To properly prepare water for injection systems, it may be

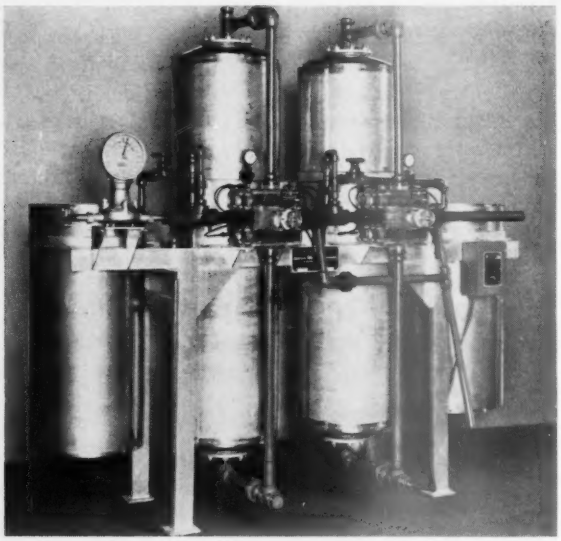

FIG. 1. A typical water deionization unit designed for airport installation. Manufactured by the American Water Softener Company, this unit is supplied ready to be attached to existing water lines. It produces 20 gpm of deionized water having a total dissolved solids content of less than 0.5 ppm. This particular unit is being used to supply water for the water-methanol mixture injected into the Rolls Royce Dart engines of the Continental Air Lines' Viscounts.

filtered to remove particles of undissolved solids and then passed through an ion exchange column for the removal of the dissolved ionic particles.

The concentration of dissolved solids in natural water varies throughout the world. In some places in our country, the dissolved solids content of natural water is sufficiently high to cause deterioration of engine performance after only 100 hours running time. This results from the deposition of thin films of minerals on engine parts as the result of the vaporation of the water. The deposition of these thin films of the nonvolatile minerals is sufficient to alter the contours of the compressor blades and burner chambers, causing a rapid loss of engine efficiency, coupled with an increase in the rate of fuel consumption.

The heating of the water also causes a chemical reaction in certain hard waters in which calcium bicarbonate is converted to insoluble calcium carbonate, forming a thick crust on metal surfaces and diminishing gas flow. This is similar to the action which often takes place in tea kettles in which a thick deposit of lime forms on the bottom and sides of the vessel.

Raw water, whether it comes from wells, rivers, lakes, or reservoirs, has a number of impurities. We often think of rainwater as being "pure," but, although it is distilled from the ocean by solar energy, the formation of raindrops or fog particles is concurrent with the absorption of carbon dioxide and dust particles from the air, and often of oxides of nitrogen. Thus, rainwater is often a mixture of carbonic and nitric acids in great dilution. The rainwater then leaches through the ground where sodium, calcium, magnesium, iron, and other positive ions are picked up, along with negative ions, such as silicate, sulfate, chloride, and phosphate. Depending upon the nature of the soil, the depth of the water supply, the rate of drainage, and many other factors, raw water supplies can be expected to have more or less of these and other impurities. An idea of the treated, "finished" tap water now available in some typical cities of this country is shown in Table 1.

A quick and convenient check on the relative purity of filtered water may be made electrically by measuring the resistance or conductance of a sample. It has been calculated that theoretically pure water would have a resistance of 26,000,000 ohms or a conductance of 0.038 micromhos. The best approach to this theoretical figure was 0.043 micromhos, obtained after 28 distillations of the same in quartz laboratory apparatus.

Water which has been deionized with Amberlite ion exchange resins can come very close to the last figure. Water which has passed once through a column of these resins may demonstrate a resistance as high as 18,000,000 ohms or a conductance of 0.056 micromhos. One mho equals approximately 0.5 ppm of dissolved solids. Such water more than fulfills the recommendation of no more than ten parts per million of total solids, as suggested by Pratt & Whitney for use in the J-57 engine. Conductivities of several types of prepared waters are shown in Table 2.

Deionizing Units

Deionizing units for industrial and commercial applications are available from many water treatment concerns. These range from small laboratory size units, producing a few lbs. of deionized water per day, to large commercial installations capable of delivering hundreds of gallons per minute. The proper rate of flow of water through the ion exchange resin is determined by design factors of the deionizing equipment.

The Amberlite ion exchange resins are supplied as small bead-like grains. These are placed in tanks (the column) into which tap water flows at the top. The water is deionized as it flows downward through the column of beads and is ready for use when it flows out of the bottom. A single passage of water through the column is sufficient to remove the ionic materials.

Amberlite ion exchange resins are products of Rohm & Haas Company of Philadelphia. In 1936, this company obtained the first basic patents for the production of synthetic ion exchange resins and manufactured these in 1939 for the first time. The introduction of synthetic resins for ion exchange brought about controlled uniformity of action, longer service life, and wider application of ion exchange than had previously been possible with naturally occurring materials, such as greensands. Applications of the ion exchange principle are now found in medicine, water softening, water deionizing, recovery of radioactive wastes, uranium metallurgy, wine making, sugar processing, chemical processing, and other industries and professions.

The actual performance of the Amberlite ion exchange resins is fairly simple. Two distinct resins are needed to deionize water. Cation exchange resins, like Amber-

lite IR-120, accept positive ions, like those of Ca^{++}, Mg^{++}, Na^{+}, Fe^{++}, etc. Since the principle of *exchange* is involved, this resin releases one hydrogen ion for each positive electrical charge picked up. Anion exchange resins, such as Amberlite IRA-400, pick up negatively charged ions, like Cl^{-}, SO_4^{--}, HCO_3^{-}, etc. and replace them with OH^{-}. In this way, both positive and negative mineral ions are removed from the water. In their place H^{+} and OH^{-} are added, and since these two ions unite to form H_2O, the total effect is that the minerals are removed and replaced with water. In instances where water supplies may contain high molecular weight organic compounds in solution, it is suggested that Amberlite IRA-402 be used instead of Amberlite IRA-400 because the highly porous nature of the resin beads of this exchanger are particularly resistant to fouling by such organic molecules.

Eventually, depending upon the amount of water which passes through the ion exchange resins and upon the quantity of impurities in the supply, the resins will become exhausted. Before this point is reached, and before soluble minerals leak through the column as a result of exhaustion, the ion exchange resins should be regenerated and brought back to their original condition. The procedure is simple.

Backwashing is the first step in the regeneration cycle. This "unpacks" the resin beads and washes out possible foreign bodies which may have passed the filters, and, in the case of single column (Monobed) units, performs a mechanical separation of the anionic and cationic resin beads. Actual regeneration is accomplished by treating the cationic resin bed with dilute sulfuric acid (which replaces the accumulated ions with hydrogen, and elutes the redissolved ions into the backflow), while the anionic resin bed is treated with dilute sodium hydroxide (which elutes the anions which the resin has removed from the raw water, and replaces them with hydroxyl ions). When the regeneration is completed, a final washing removes residual regenerant solutions. In Monobed units, compressed air is bubbled into the column to remix the anionic and cationic beads, and the ion exchange resin bed is ready for another operational cycle. Since the regenerant chemicals are relatively inexpensive and since they are used in considerable concentration relative to the concentration of minerals in solution, the regeneration cycle is inexpensive in terms of both time and money. Some of the commercially available water deionizing units, which are now being installed in airports, have "pushbutton" regeneration control, which is automatic; other units can be regulated in the usual manual fashion.

For actual airfield installations, a number of good quality deionizing units are available. Some of these are skid-mounted and need only be connected to existing water supplies to ready them for operation. Based on the expected demands of the new planes, such units are designed to produce 20 gal. per minute or more of deionized water. This water may be stored in clean, noncorrosive tanks for later transfer to the planes

TABLE 1
Typical Water Supply Quality for Some United States Cities
(From U.S. Geological Survey)

City and State	Conductivity, in micromhos	Total Dissolved Solids, ppm	Total Water Hardness, ppm
Boston, Mass.	41.3	29	12
Hartford, Conn.	39.7	27	12
Providence, R.I.	74.6	52	24
Buffalo, N.Y.	285	164	124
New York City	121	75	50
Newark, N.J.	70.6	43	25
Philadelphia, Pa.	238	151	96
Pittsburgh, Pa.	569	373	124
Washington, D.C.	236	156	102
Wheeling, W.Va.	345	224	128
Newport News, Va.	164	110	68
Baltimore, Md.	...	81	50
Charlotte, N.C.	75.4	45	22
Columbia, S.C.	97.1	63	29
Atlanta, Ga.	63	48	20
Albany, Ga.	325	202	102
Pensacola, Fla.	87	56	20
Birmingham, Ala.	193	118	91
Louisville, Ky.	251	146	90
Gulfport, Miss.	214	177	3
Memphis, Tenn.	173	122	59
Dayton, Ohio	654	391	358
Columbus, Ohio	1,000	227	60
Cleveland, Ohio	286	169	128
Indianapolis, Ind.	486	226	222
Chicago, Ill.	273	168	138
Detroit, Mich.	...	132	98
Milwaukee, Wis.	265	152	131
Minneapolis, Minn.	182	126	68
Omaha, Neb.	629	418	230
Des Moines, Iowa	341	212	78
Kansas City, Kan.	770	520	276
St. Louis, Mo.	...	241	96
Houston, Tex.	734	433	50
New Orleans, La.	285	166	84
Denver, Colo.	423	...	139
Phoenix, Ariz.	1,490	887	422
Albuquerque, N.M.	471	340	85
Salt Lake City, Utah	835	555	448
Los Angeles, Calif.	1,100	692	125
Portland, Ore.	...	30	9
Seattle, Wash.	...	37	18

TABLE 2
Conductivity of Water Obtained From Various Sources

Type of Water	Quality, in micromhos
Theoretical maximum quality	0.038
Water distilled 28 times in quartz	0.043
Water deionized with Amberlite ion exchange resins	0.056
Water triple distilled in glass	1.0
Water single distilled in glass	2.0
U.S.P. grade distilled water	2.0 to 5.0

TABLE 3
Recommended Water Requirements for the Pratt & Whitney J-57 Engine

Total dissolved solids, ppm	10
Approximate rate of water use, lbs./hour/engine	40,000
Approximate injection water pumping rate, gpm/engine	80
Tank location	
Boeing 707 Fuselage	
Douglas DC-8 Wing base	

or the output of the deionizing unit may be coupled directly to the plane's water tanks.

The production of deionized water is definitely here to stay as a facility of all major airports. Through using deionized water, a number of the new planes will minimize engine maintenance and down time. Installation of deionizing units and their subsequent operation should not exceed distillation costs, and the absence of any need for fuel, coupled with the higher quality of water produced, makes the deionizing unit a highly efficient and productive system.

✦ ✦ ✦

Microschlieren (Continued from page 40)

quite flexible, with a wide range of magnifications, objectives of different focal lengths and apertures, and virtually unlimited possibilities in the types of schlieren or phase contrast modification used, these results are not intended to be indicative of all possible configurations.

In conclusion, the authors feel that the microschlieren technique should serve as a useful tool for detailed study of small flow fields, such as those near leading edges, about probes immersed in high-speed boundary layers, regions involving the injection of cooling gases into a hot boundary layer, transition regions in the boundary layer, shock-wave boundary-layer interactions, etc., and warrants consideration as the primary flow visualization technique in many applications and as a complementary technique in others.

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Hydro-Fatigue Test . . . (Continued from page 47)

confirmed the desirability of the fail safe design philosophy.

Even though our most significant failures occurred at test cycles corresponding to high operational times, major findings from the hydro-fatigue test are being incorporated on C-130 aircraft in service and production as rapidly as possible. We are recommending this conservative approach for two major reasons. First, with the present state of the art of fatigue analysis there is no reliable way to relate our hydro-fatigue test results with service; hence, we are not sure when, if ever, similar failures will occur in service. Second, if failures do occur, fixes or repairs on an individual basis could be excessively costly and consume excessive airplane down time.

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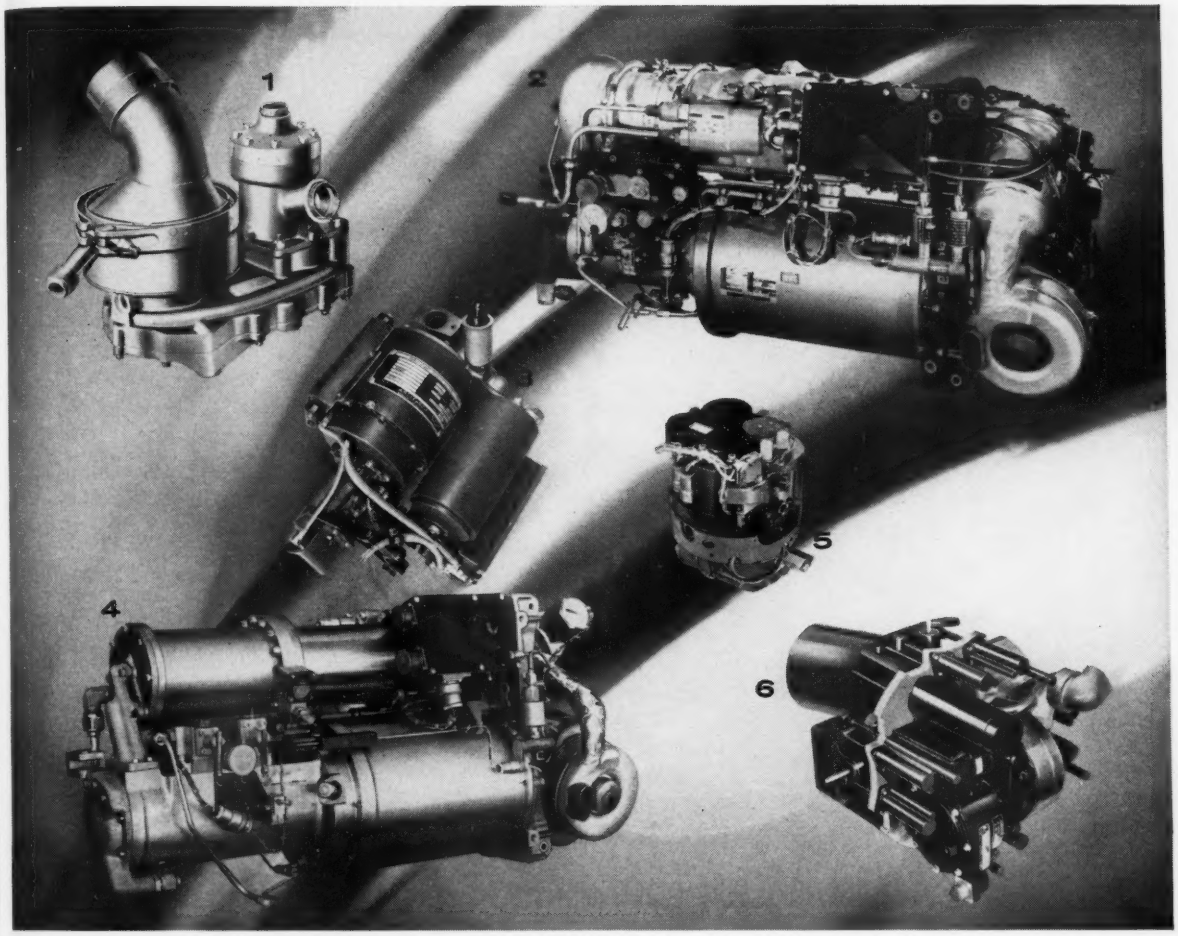

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GPL combined guidance

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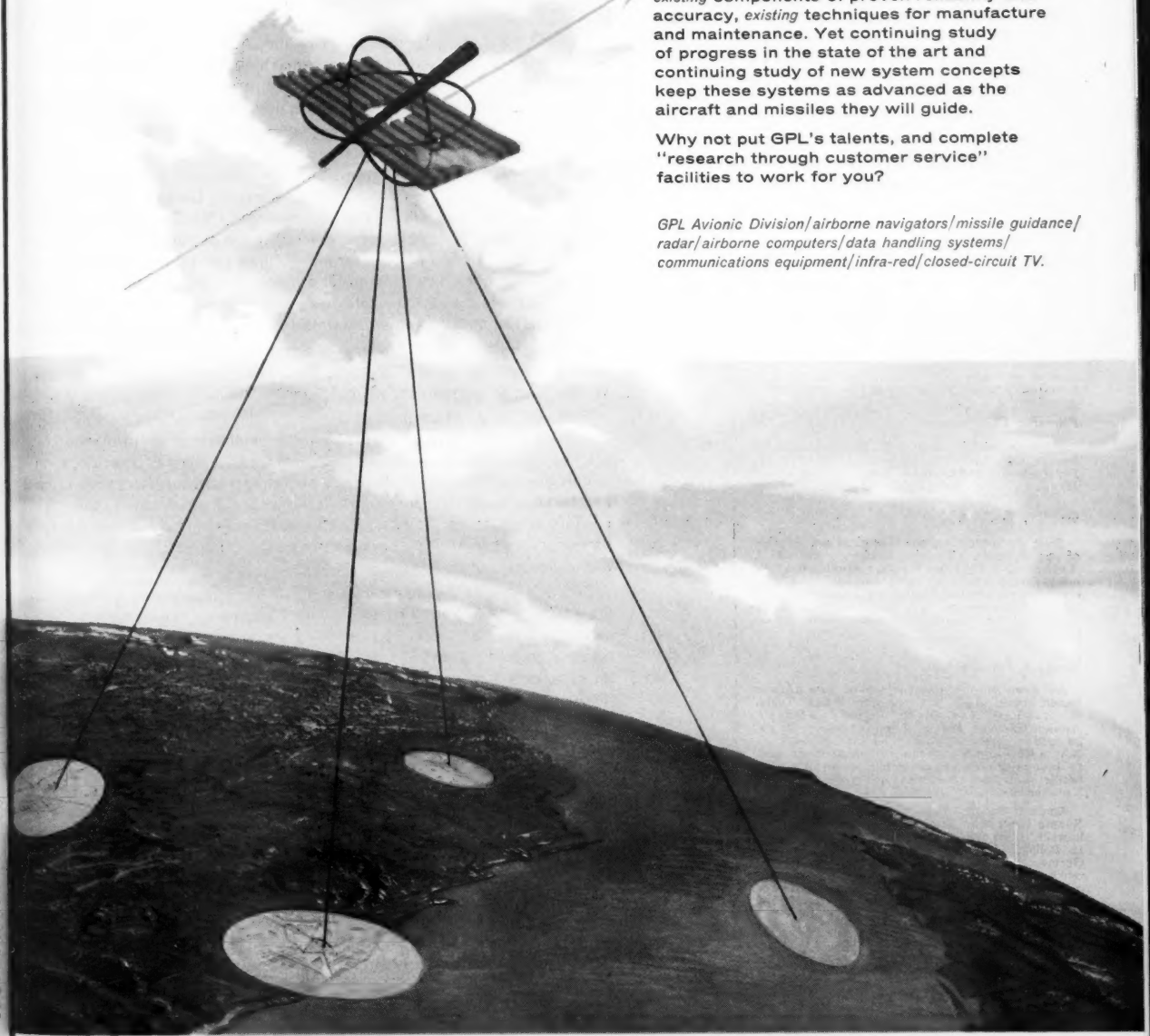

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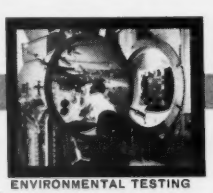

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field for vertical cascades with harmonically oscillating blades. The fluid medium is assumed to be incompressible and nonviscous, and the vibrations of the blades are considered to be independent—i.e., their amplitude and phase do not necessarily coincide.

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Fellow Engineers and Scientists:

My company has asked me to tell you of the unusual opportunities in operations research at System Development Corporation. These range from positions for engineers and scientists who would like to develop their skills working in a team under an experienced leader to opportunities for those who are looking for positions of leadership. I hope that the following account of our work will lead you to inquire for further information.

Briefly, SDC's business is automated decision-making systems. More fully, we develop large scale, computer-based information processing systems in which the computer is used as an on-line, centralized control element for a system operating in real-time. At this stage of the art these systems are semi-automatic, the man-machine type in which man shares the repetitive control function with the computer. Our work is concept-oriented, rather than hardware-oriented, and deals with problems of over-all system design, data processing development, and man-machine system training.

The most fully developed large-scale semi-automatic system is the SAGE (Semi-Automatic Ground Environment) Air Defense System. We have a major responsibility in the development of SAGE. Our experience and unique team skills have led to diversification of our activities; we now have important contracts for other major military and government systems vital to our country. The demand for our services is reflected in our growth from 70 to more than 2,700 employees since 1955, and the intriguing possibilities of automated decision-making are only beginning to be realized.

In this brief message, I can only suggest the variety of operations research problems at SDC. Perhaps the most important point is that this variety is limited only by the imagination and initiative of our scientists.

Some examples of areas of work are: (1) allocation of decision-making functions between man and machine for optimal system performance; (2) measures of system capacity and system performance; (3) exploration and evaluation of design changes by operational gaming; (4) quality control and testing of operational computer programs; (5) allocation of computer capacity among several system functions; (6) scheduling and costing of production of operational computer programs; (7) optimal assignment of mixed weapons to targets.

SDC recognizes the importance of a well planned research program for the vitality and future of the company, and we are carefully organized to carry out such a program. The following are some areas our operations research people are involved in: (1) simulation and operational gaming techniques in problems of control systems; (2) information retrieval and theory of information processing; (3) medical data processing; (4) universal language for computer programming; (5) logistics. We have unusual facilities for research at SDC—these include one of the largest computer facilities in the world and outstanding simulation laboratories.

We have given considerable thought to organizing the activities at SDC to provide for professional development and self-expression. Operations research professionals are carefully assigned so that their individual talents are matched with company needs. These assignments are reviewed regularly to make sure that developing talents are directed into new company opportunities. We regard the publication of research articles and participation in professional societies as activities important to the company. We encourage new ideas and provide the time and means to explore them.

SDC is one of the leaders in a field which will have a remarkable technological and scientific development. It is a new and vigorous company with a bright future. I encourage you to join us.

Please write Mr. R. W. Frost at the address below if you wish to pursue this invitation.

William Lanouette

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William Karush
Assistant Director for Research
Operations and Management Research
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elastic, and inertial forces to the design and construction of aeroelastic models.

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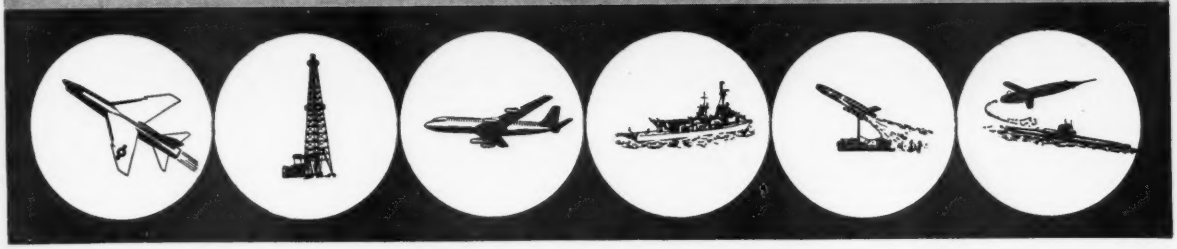

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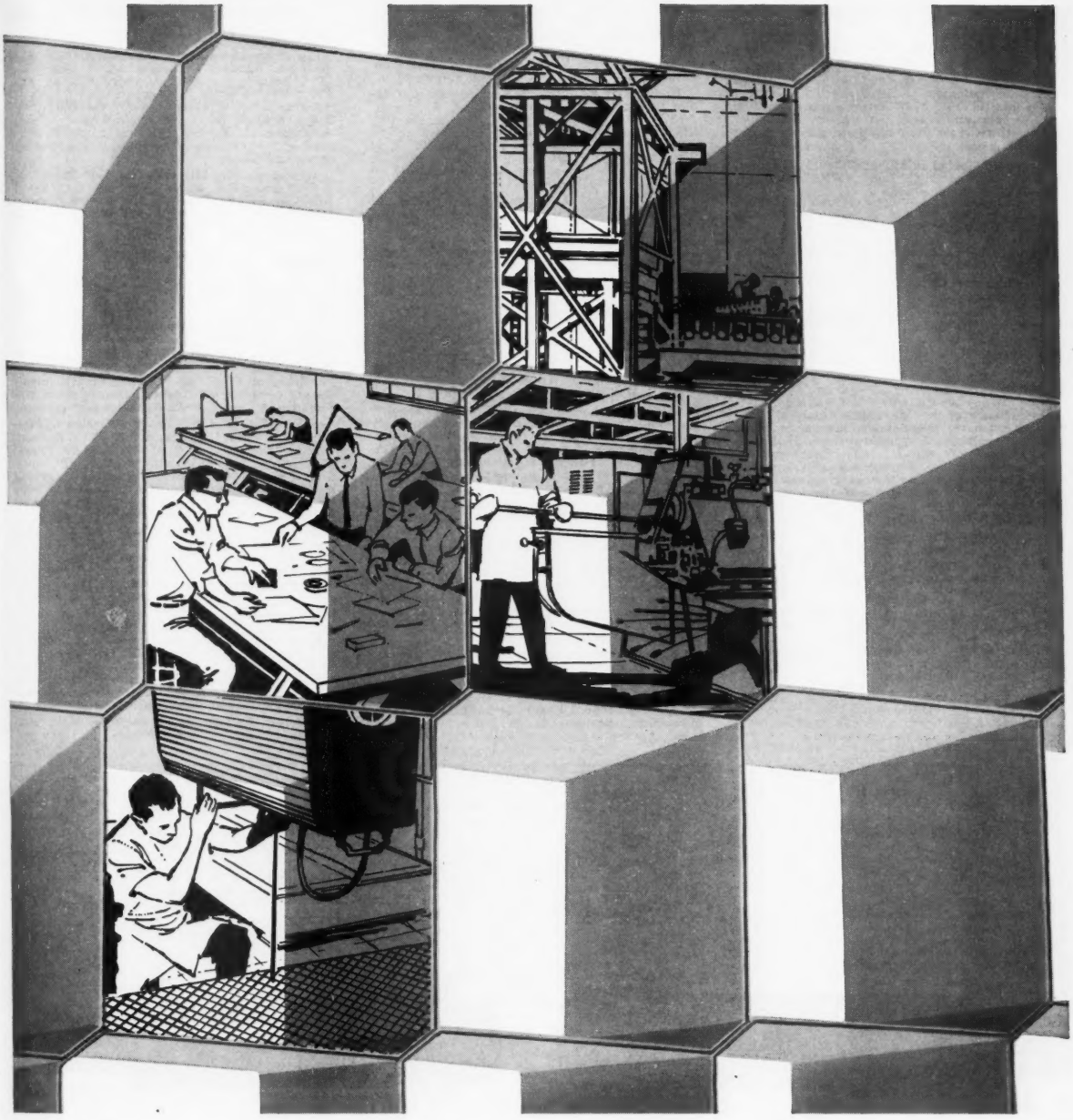

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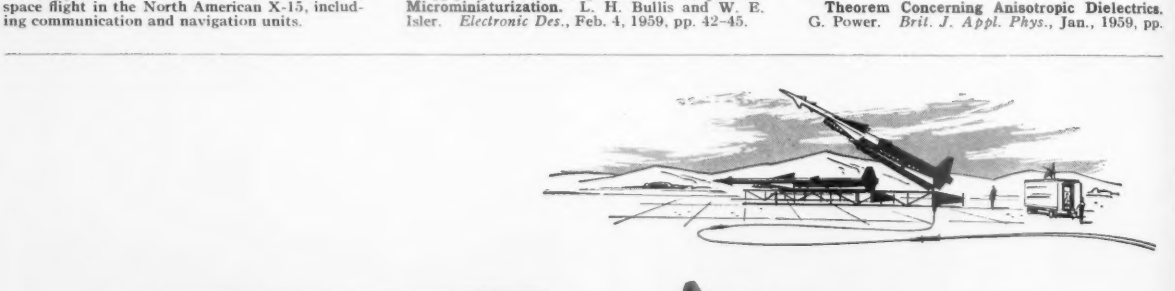

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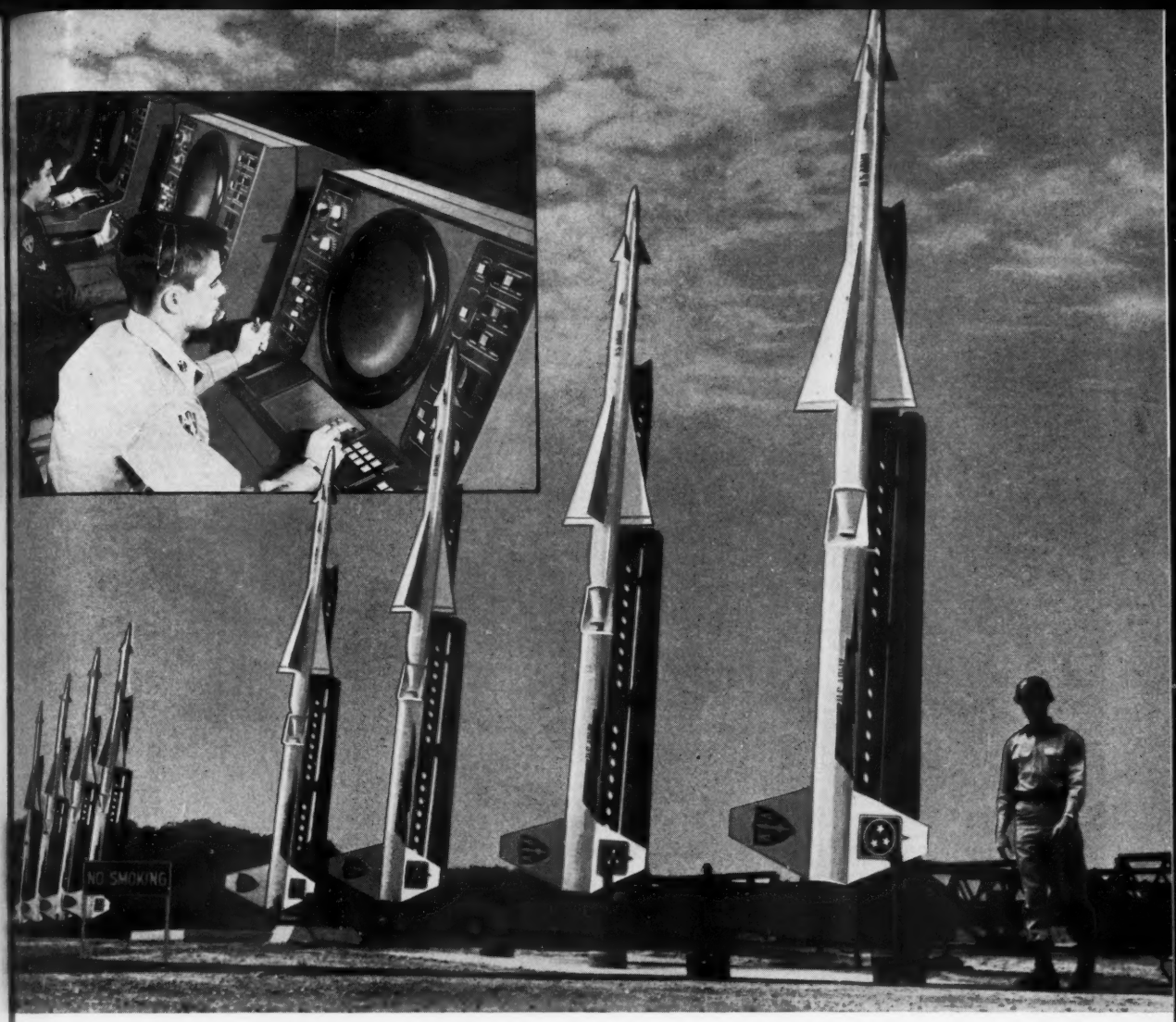

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A Look at Reinforced Plastics. J. P. Kushnerick. *Aircraft & Missiles Mfg.*, Feb., 1959, pp. 18–20. Discussion covering the increased applications of reinforced plastics in the aircraft and missile industry, as well as its drop in total pound usage. New materials and processes are also discussed.

Plastics in Electra. R. P. Routt and E. A. Green. *Aircraft & Missiles Mfg.*, Feb., 1959, pp. 23–26. Discussion of the application of plastics, including problems related to the replacement of traditional metallic structures. Some typical reinforced plastic parts are examined, and various tools required for their construction are considered.

Silicone Elastomer. Robert Treat, Jr. *Aircraft & Missiles Mfg.*, Feb., 1959, pp. 35–37. Evaluation of the properties and the use of silicone elastomer as a room- and high-temperature sealant.

What's Ahead for Castable Polyurethanes. G. M. Le Fave and Robert Gamero. *Ind. Labs.*, Feb., 1959, pp. 43–46. Discussion on the development, properties, and applications of castable polyurethane; its advantages are stressed.

Polyurethane Foam. T. P. Dougan. *Aircraft & Missiles Mfg.*, Feb., 1959, pp. 28–32. Discussion of the advantages and applications of flexible and rigid polyurethane foams.

Testing Methods

New Test Methods Give Reliable Cermet Data. *Space/Aeronautics*, Feb., 1959, pp. 86–92. Description of test equipment developed for obtaining mechanical properties of brittle cermets from tensile specimens. A comparison of tests is made.

A Machine for Evaluation of High-Temperature Alloys Under Combined Static and Dynamic Stresses. P. E. Hawkes and C. H. Ek. *ASTM Bul.*, Jan., 1959, pp. 46–51. Description of a machine capable of subjecting a specimen to a stress-rupture loading combined with a high-frequency fluctuating stress to simulate service loadings typical of highly stressed components. The test temperature range is from 1,000°F. to 1,800°F. Data are presented as modified Goodman type diagrams and as three-dimensional diagrams incorporating axes of static loading, dynamic loading, and time.

Eksperimental'naia Proverka Zakonov Izotropii i Zapazdyvaniia pri Slozhnom Nagruzhenii. V. S. Lenskii. *AN SSSR Otd. Tekh. Nauk Izv.*, Nov., 1958, pp. 15–24. 20 refs. In Russian. Description of experiments performed to verify two previously established laws on the behavior of materials under complex loading which define the vector properties of materials.

Mathematics

Sobre a Introdução do Conceito de Vetor. L. H. B. Hegenberg. *ITA-Eng.*, Nov.-Dec., 1958, pp. 77–80. In Portuguese. Analysis of the advantages of introducing the concept of the vector as an invariant in certain transformations.

On Solutions of $\Delta V + V = 0$ in an Exterior Region. Philip Hartman. *Johns Hopkins U. Dept. Math. TR 8 (AFOSR TN 58-984) [AD 205914]*, Nov., 1958. 12 pp.

Um Método para Solução de Equações Lineares de Diferença ou de Recorrência Dentro de um Domínio Fechado. P. C. Dunne. *ITA-Eng.*, Nov.-Dec., 1958, pp. 61–72. In Portuguese. Development of a systematic method for the solution of linear difference equations. The applicability of the procedure to various specific problems is evaluated.

(*Continued on page 92*)

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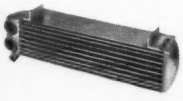

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ACOUSTICS, SOUND, NOISE

ACOUSTICAL RESONANCES PRODUCED BY COMBUSTION OF A FUEL-AIR MIXTURE IN A RECTANGULAR DUCT. Isidor Elias. ASA J., Mar., 1959, pp. 296-304. USAF-sponsored experimental study conducted with a model ram-jet combustor to explore the mechanisms which maintain high-frequency combustion pressure oscillations in the air-breathing jet engine. Results show that pressure oscillations characteristic of transverse acoustic modes occur as fuel-air mixtures approach stoichiometric values. High-speed motion pictures of the combustion zone during screech indicate that the flame fronts are serrated, the number of serrations being proportional to screech frequency. High-amplitude oscillations occur under intense screech conditions, and high-turbulence levels produce screech at lower values of fuel-air mixture.

AERODYNAMICS, FLUID MECHANICS

Aerothermodynamics

A METHOD FOR COMPUTING TURBULENT HEAT TRANSFER IN THE PRESENCE OF A STREAMWISE PRESSURE GRADIENT FOR BODIES IN HIGH-SPEED FLOW. N. B. Cohen. US, NASA Memo. 1-2-59L, Mar., 1959. 77 pp. 25 refs. Derivation of a modified Reynolds analogy between skin friction and heat transfer which depends upon local pressure gradient. Exact and approximate solutions are derived from the differential equations, the exact solution is applicable for arbitrary initial (transition) conditions and the approximate solutions require fully developed turbulent flow from stagnation point or leading edge. The exact solution (restricted to stagnation initial conditions) and the approximate solutions are shown to agree with one another within 5% when applied to several blunt shapes. The present solutions generally predict the measured heating rates on these bodies within the accuracy of the measurements provided transition began upstream of the peak heating region.

MEASUREMENTS OF LOCAL HEAT TRANSFER AND PRESSURE ON SIX 2-INCH-DIAMETER BLUNT BODIES AT A MACH NUMBER OF 4.95 AND AT REYNOLDS NUMBERS PER FOOT UP TO 81×10^6. Appendix A - DERIVATION OF SHAPE OF BLUNT-NOSED BODY HAVING A PRESCRIBED PRESSURE DISTRIBUTION. Appendix B - APPLICATION OF IDEAL-GAS VELOCITY MEASUREMENTS TO REAL-GAS HEAT-TRANSFER CALCULATIONS. Morton Cooper and E. E. Mayo. US, NASA Memo. 1-3-59L, Mar., 1959. 39 pp. 28 refs. Investigation of laminar flow over flat-nosed and hemispherical-nosed bodies having a surface finish from 10 to 20 μin. at the highest test Reynolds Number of 77.4×10^6. Although it was repeatedly possible to measure completely laminar flow at this Reynolds Number for the hemisphere, it was not possible to observe completely laminar flows on a flat-nosed body for similar conditions. The pressures measured on the hemisphere agreed very well with those of the modified Newtonian theory, whereas the pressures on all other bodies, except the flat-nosed body, were bracketed by those of the modified Newtonian theory both with and without centrifugal forces.

A STUDY OF THE ABLATION PROCESS WITH VARIABLE THERMAL PROPERTIES IN A SEMI-INFINITE SLAB. J. V. Beck. Avco Res. & Adv. Devel. Div. RAD 2-TM-58-103, Jan. 30, 1959. 20 pp. Presentation of exact solutions of pertinent differential equations for temperature distributions and ablation rates. These solutions account for temperature variation of thermal properties (specified heat, thermal conductivity, and diffusivity) and provide means of independent check for the transient numerical ablation calculations performed on analog and digital computers. A technique is developed allowing for application of quasi-stationary results to the solution of certain transient problems involving temperature dependent thermal properties and time dependent surface heat flux.

CALCULATION OF CONVECTION HEAT TRANSFER TO NON-ISOTHERMAL SURFACES EXPOSED TO A FLUID STREAM WITH WEDGE

TYPE SURFACE PRESSURE GRADIENT. J. P. Hartnett, E. R. G. Eckert, and Roland Birkebak. USAF WADC TR 57-753 [AD 142236], July, 1958. 37 pp. 19 refs. Development of a single design procedure for calculating the local and total heat-transfer rates from nonisothermal surfaces with prescribed wall temperature distributions. An extension of the method to cover heat transfer from nonisothermal surfaces with arbitrary pressure gradient is proposed. A solution for the inverse problem of calculating the wall temperature distribution along surfaces with a prescribed heat flow distribution is presented for laminar wedge-type flows and for turbulent flow with zero pressure gradient.

SIMPLIFIED ANALYTICAL METHOD TO DETERMINE SURFACE TEMPERATURE IN A SOLID HEAT SINK. Appendix A - RESPONSE TIME. Appendix B - CALCULATION OF THE EQUILIBRIUM TEMPERATURE. J. V. Beck. Avco Res. & Adv. Devel. Div. RAD 2-TM-58-131, Dec. 11, 1958. 25 pp. Presentation of methods by which surface temperature histories in heat sinks with variable conditions can be calculated rapidly by hand. The computations are implemented by the use of graphs for specific homogeneous and composite heat sinks. Insight into the solid heat sink problem is given by introducing concepts of equilibrium temperature and response time for variable-thermal-property composite heat sinks.

THE ABLATION OF REINFORCED PLASTICS IN SUPERSONIC FLOW. G. W. Sutton. G-E MOSD AORM 3, July 26, 1957. 22 pp. Investigation of a number of plastics reinforced with inorganic fibers for possible use as a shell material for a re-entry capsule. A rocket motor exhaust may be used to simulate hypersonic heating for flight Mach Numbers greater than eight at 70,000 ft. The ablation rates of certain inorganic reinforced plastics are sufficiently low so that they may be used for thermal protection. Data have been presented by which the calculations can be made of the thickness that will ablate. The temperature profile is an inverse exponential when changes in the ablation rate occur slowly in comparison to the time required for the ablation rate to readjust to a step heating function. The lowest ablation parameter was exhibited by plastics reinforced with Refrasil, which is 96% silica. All reinforcements, except glass, seemed to suffer from mechanical weakness at elevated temperatures.

Boundary Layer

A STUDY OF THE USE OF OPTIMAL COORDINATES FOR SOME VISCOUS FLOW PROBLEMS. K. T. Yen. Rensselaer Polytech. Inst. Dept. Aero. Eng. TR AE5805 (AFOSR TN 59-11) [AD 208592], Apr., 1958. 43 pp. Study of the use of optimal coordinates for boundary-layer flows of the wedge type and a simple shear flow over a flat plate. The optimal coordinates for both types of problems are determined and the physical significance of the solutions pertaining to their use is discussed. For the boundary layer problem of a flat plate and any one of the wedge flow type, a new definition of boundary-layer thickness is proposed. For the simple shear flow problem, it is shown that parabolic coordinates can be used as the optimal coordinates. Methods of solution of this problem are given and discussed.

ON THE SEPARATION OF GAS MIXTURES BY SUCTION OF THE THERMAL-DIFFUSION BOUNDARY LAYER. Appendix - CAPILLARY THEORY OF SEPARATION. V. C. Liu. Quart. J. Mech. & Appl. Math., Feb., 1959, pp. 1-13. 20 refs. Study of the formation and characteristics of the boundary layer of thermal diffusion existing along the surface of a heated wall over which flows a mixture of gases of unequal molecular weights. A new method of separating gas mixtures is developed. The thermal-diffusion boundary layer is analyzed, and the strong stabilizing effect of suction on the laminar flow briefly discussed. A limiting ratio of suction against free-stream velocity for the maintenance of laminar flow is derived, and the rate of attaining the equilibrium-concentration profile is estimated.

THE CHARACTERISTICS OF ROUGHNESS FROM INSECTS AS OBSERVED FOR TWO-DIMENSIONAL, INCOMPRESSIBLE FLOW PAST AIRFOILS. W. S. Coleman. J. Aero/Space Sci., May, 1959, pp. 264-280, 286. 23 refs. Theoretical and experimental investigation covering the manner of distribution and magnitude of the roughness generated in flight by the impact of insects, as well as its effect upon the stability of the laminar boundary layer. The characteristics of the roughness profile consist principally of a pronounced peak near the leading edge, followed by an extensive area of surface over which there is a much reduced and gradually diminishing value of the excrescence height. Further, it is shown that, if the severe leading-edge roughness, or its effect upon the boundary layer, can be eliminated, then the downstream roughness causes no disturbance to the passage of a laminar layer - i.e., the surface, though roughened, is aerodynamically smooth. Moreover, it appears that the conditions defining the upstream boundary to this region of insignificant roughness are fundamentally the same as those which determine the critical state for transition at an artificial disturbance of a three-dimensional character.

ZUR RATIONELLEN BERECHNUNG LAMINARER UND TURBULENTER KOMPRESSIBLER GRENZSCHICHTEN MIT WÄRMEÜBERTRAGUNG. Norbert Scholz. ZFW, Feb., 1959, pp. 33-39. 11 refs. In German. Presentation of an approximate procedure for the calculation of laminar and turbulent boundary layers with arbitrary pressure and wall temperature for engineering use. The influence of compressibility and heat transfer on the boundary layer flow is taken into account. Examples showing the application of the procedure are given.

THE INTERACTION OF AN OBLIQUE SHOCK WAVE WITH A LAMINAR BOUNDARY LAYER. R. J. Hakkinen, I. Greber, L. Trilling, and S. S.

Abarbanel. US, NASA Memo. 2-18-59W, Mar., 1959. 49 pp. 12 refs. Theoretical and experimental investigation of the interaction problem. Detailed measurements of pressure distribution, shear distribution, and velocity profiles were made during the interaction of oblique shock waves with laminar boundary layers on a flat plate. From these measurements a model is derived to predict the pressure levels characteristic of separation and the length of the separated region. The adverse pressure gradient due to a shock wave is shown to cause a decrease in the wall shear upstream of the shock wave.

A DETAILED STUDY OF THE INTERACTION OF A 14° SHOCK WAVE WITH A TURBULENT BOUNDARY LAYER AT M = 2.9. I. E. Vas. Princeton U. Dept. Aero. Eng. Rep. 296 (AFOSR TN 55-201), Apr., 1955. 51 pp. Investigation of the entire interaction region using small total pressure probes facing both upstream and downstream. The wall static pressures and separation points are obtained for a series of interactions generated by wedges varying from 8° to 14°. The separation region extended about 6.5 boundary layer thicknesses in length and 3/4 boundary layer thicknesses in height. The pressure at the separation point is about 2.1 times the free stream static pressure and is found to be relatively independent of shock strength.

INVESTIGATION OF FREE-MOLECULE AND TRANSITION FLOWS NEAR THE LEADING EDGE OF A FLAT PLATE. E. L. Harris. UTIA Rep. 53, Nov., 1958. 86 pp. 17 refs. AFOSR-supported test results from pressure measurements made in flow over a plate in a low-density wind tunnel. Reasonably good agreement was obtained between orifice impact pressures measured less than one mean free path from the leading edge and a theoretical pressure calculated on the assumption that molecules entering the orifice probe came from the region upstream of the plate and from the plate surface after a diffuse reflection from it. Velocity gradients that existed, even without the plate in the stream, made the results concerning the nature of the flow over the complete plate qualitative. A quantity analogous to a boundary-layer displacement thickness was defined in terms of the impact pressures with and without the plate in the flow. This quantity began about one mean free path upstream of the leading edge and grew approximately linearly with distance.

AN EXPERIMENTAL STUDY AT A MACH NUMBER OF 3 OF THE EFFECT OF TURBULENCE LEVEL AND SANDPAPER-TYPE ROUGHNESS ON TRANSITION ON A FLAT PLATE. R. A. Jones. US, NASA Memo. 2-9-59L, Mar., 1959. 43 pp. 13 refs. Results of tests over a range of Reynolds Numbers from 0.8×10^6 to 1.8×10^6 per in., the heat transfer between the plate and the stream being considered negligible. Transition locations were determined by an optical method. This method was indicative of a permanent change in the boundary-layer density distribution rather than the onset of turbulent bursts. Results showed that, when transition was influenced by roughness, it moved in a way similar to its movement on a smooth plate - i.e., it gradually approached the roughness location with either an increase in unit Reynolds Number or an increase in turbulence level.

THE THREE DIMENSIONAL INCOMPRESSIBLE LAMINAR BOUNDARY LAYER ON A SPINNING CONE. Ching-Sheng Wu. Appl. Sci. Res., Sect. A, No. 2-3, 1959, pp. 140-157. 13 refs. AFOSR-sponsored analysis of the motion of an incompressible viscous fluid induced by a spinning cone and presentation of similar solutions for the relevant steady state boundary equations. The motion is assumed to be steady and axially symmetric. Some of the numerical results are shown to be obtainable from the Kármán-Cochran solution for the infinite disc. It is shown that at large distance from the vertex of the cone the thickness of the layer is constant, and that the pressure at the solid wall decreases with increasing distance from the vertex.

THE LAMINAR BOUNDARY-LAYER FLOW ON ROTATING CYLINDERS. II - THIN CYLINDERS. Shao-Wen Liu. Cornell U. Grad. Sch. Aero. Eng. Rep. (AFOSR TN 57-298) [AD 132369], June, 1957. 133 pp. 17 refs. Derivation of the boundary-layer equations for a cylindrical blade rotating with a constant angular speed about an axis perpendicular to the cylindrical axis and extension, from the existing solution, to allow the axis of rotation to be located arbitrarily with respect to the leading edge of the blade. The case of cylinders with small thickness is covered. The cylindrical symmetry is represented by assuming a universal velocity polynomial in terms of the chordwise coordinate for the chordwise potential flow. As in the flat-plate case, solution is obtained by means of series expansions in terms of the appropriate parameters. The deviations of the results from infinite-cylinder flow are found to be caused mainly by the modification of the outstanding pressure-gradient terms. Such effects on the chordwise flow can be favorable or adverse, depending on the location of the axis of rotation.

EXPERIMENTAL EVIDENCE OF THREE-DIMENSIONAL PERTURBATIONS IN THE REATTACHMENT OF A TWO-DIMENSIONAL LAMINAR BOUNDARY LAYER AT M=2.05. Jean Ginoux. Appendix - AXIAL VORTICITY IN STEADY IDEAL FLUID FLOW. Jean Smolderen. TCEA TN 1, Nov., 1958. 31 pp. 12 refs. USAF-sponsored investigation using backward facing step models completely spanning the working section. Surface flow was observed by a sublimation technique and detailed spanwise surveys are made in the reattachment region of the flow with total head probes. Strong regular and repeatable spanwise perturbations are observed which could be explained by irregularities either in the airflow upstream of the models or in the models themselves.

COUCHE LIMITE TURBULENTE: CORRELATIONS SPATIO-TEMPORELLES ET SPECTRES DE VITESSES. A. Favre, J. Gaviglio, and R.

Dumas. France, ONERA Pub. 92, 1958. 107 pp. 17 refs. In French. Experimental investigation of the turbulent boundary layer on a flat plate with zero pressure gradient. Hot-wire measurements cover the intensity of turbulence, energy spectra, autocorrelations, double spatiotemporal correlations, and longitudinal fluctuations of velocity in the boundary layer. The transition is produced either by the controlled preturbulence of the flow or by roughnesses located along the leading edge. Extended measurements of double spatiotemporal correlations lead to the determination of surfaces of spatiotemporal isocorrelation with optimum lag, relative to a distance from the fixed wire to the wall equal to 3% of the boundary-layer thickness. Distances equal to 15% and 77% of the boundary-layer thickness complete these results: for macroscopic motion, upstream as well as downstream, the correlation conserves high values due to the large-scale turbulence. For distances greater than 3% an extension of the Taylor's hypothesis is used. The surfaces of spatiotemporal isocorrelation obtained with optimum lag T_m exhibit a substantial longitudinal elongation, even when relative to a fixed point in the vicinity of the wall (0.03δ).

SPACE-TIME CORRELATIONS AND SPECTRA OF WALL PRESSURE IN A TURBULENT BOUNDARY LAYER. W. W. Willmarth. US, NASA Memo. 3-17-59W, Mar., 1959. 22 pp. 12 refs. Experimental investigation to measure the statistical properties of the fluctuating wall pressure produced by a subsonic turbulent boundary layer. Results indicate that the ratio of the root-mean-square wall pressure to the free-stream dynamic pressure is a constant independent of Mach and Reynolds Numbers. Space-time correlation measurements of the pressure fluctuations whose scale is greater than, or equal to, 0.3δ (δ = boundary-layer thickness) show that a given pressure pattern is convected with a speed $U_c = 0.82U_\infty$ (U_∞ = free-stream velocity) and is essentially destroyed in a distance of 10 boundary-layer thicknesses.

ELEMENTARY ANALYSIS OF THE TURBULENT PLATE LAYER. A. K. Azad. Catholic U. Am. Paper, Jan., 1959. 10 pp. ONR-supported application of Munk's elementary theory to the turbulent boundary layer of a flat plate. The difference between the velocity profile of a flate plate and that of a circular pipe is explained. The computation of the plate velocity profile leads furthermore to a determination of the numerical value of the migration coefficient and of the diffusion coefficient occurring in the elementary theory. The experimentally found numerical value of the migration coefficient agrees both numerically and in the order of magnitude with Munk's theoretically predicted value.

Control Surfaces

EFFECT OF HORIZONTAL-TAIL CHORD ON THE CALCULATED SUBSONIC SPAN LOADS AND STABILITY DERIVATIVES OF ISOLATED UNSWEPT TAIL ASSEMBLIES IN SIDESLIP AND STEADY ROLL. K. W. Booth. US, NASA Memo. 4-1-59L, Mar., 1959. 32 pp. Investigation covering variations in horizontal-tail chord, horizontal-tail span, and vertical location of the horizontal tail. Calculations are made using the discrete-horseshoe-vortex method. The incremental span loads due to dihedral of the horizontal-tail surfaces are determined for the sideslip case. The span loads and the resulting total stability derivatives, as well as the vertical- and horizontal-tail contributions to the tail-assembly derivatives, are presented graphically for the purpose of showing the influence of the geometric variables. Variations in horizontal-tail chord are found to have a pronounced influence on most of the span loads and the resulting stability derivatives.

Flow of Fluids

REVIEW OF UNSTEADY AERODYNAMIC STUDIES IN THE FLUID DYNAMICS RESEARCH GROUP, 1955-1958. Haim Kennet and Holt Ashely. MIT FDRG Rep. 58-5 (AFOSR TR 59-6) [AD 208981], Dec., 1958. 46 pp. 27 refs. Experimental and theoretical investigation on wings, bodies, and wing-body combinations for transonic, supersonic, and hypersonic speed regimes. In transonic and supersonic flows, the method developed is an extension of an iterative technique originally proposed by Adams and Sears. It estimates aerodynamic loads on slender symmetrical configurations performing small lateral oscillations. Planar surfaces in unsteady supersonic flow are treated in two fashions. For wings with subsonic leading edges and supersonic trailing edges, strip theory is applied. For thin wings at high Mach Number M the perturbation velocity potential is expanded in a series of M^{-2}. Oscillating hypersonic airfoils are analyzed by modified piston theories. A theory for estimating unsteady loads in the nose region of blunt-nosed bodies in hypersonic flow is also described. It is based on small perturbations of an approximate steady flow field.

NUMERICAL SOLUTION OF THE FLOW OF A PERFECT GAS OVER A CIRCULAR CYLINDER AT INFINITE MACH NUMBER. F. M. Hamaker. US, NASA Memo. 2-25-59A, Mar., 1959. 33 pp. 16 refs. Calculation of the two-dimensional flow about a cylinder using Southwell's relaxation method for the subsonic region and the method of characteristics for the supersonic portion of the flow. The shapes of the sonic line and the shock wave are obtained by iteration techniques. Nonisentropic conditions of curved shock waves and vorticity are considered. The distribution of Mach Number in the flow pattern indicates that the interaction between the subsonic and supersonic regions is negligible. Comparisons are made with other theoretical methods and with experimental results.

CALCULATION OF SUPERSONIC FLOW PAST A FLAT-HEAD CYLINDER BY BELOTSERKOVSKII'S METHOD. Ruby Gold and Maurice Holt. Brown U. Div. Appl. Math. Rep. (AFOSR TN 59-199) [AD 211525], Mar., 1959. 21 pp. Determination of the surface pressure distribution and associated flow field (including the shape of the detached

shock wave) for an incident Mach Number of 5.8. Only the first of Belotserkovskii's three approximations is considered. Selected physical variables are assumed to vary linearly between the body and the shock, thereby reducing the original problem to one of solving three ordinary differential equations. The boundary conditions are obtained from symmetry conditions on the axis of symmetry, the oblique shock equations, and the condition that sonic speed is attained at the sharp shoulder. Theoretical results are compared with recent experimental data.

CYLINDRICAL BODY WITH AN INTENSE CRISIS OF DRAG. K. K. Fediaevskii and G. K. Nastiukova. Sov. Phys. - Tech. Phys., July, 1958, pp. 1,435-1,439. Translation. Investigation of a body in which the laminar boundary layer breaks away at about the thickest part of the body while the breakaway of the turbulent boundary layer takes place near the trailing end of the body. The results show a radical change in the pressure distribution, while the drag coefficient falls to about a fifth. It is concluded that the breakaway of the laminar boundary layer takes place near the thickest part, while in the case of a turbulent boundary layer no breakaway actually takes place.

OBRAZOVANIE KOLEBANII V SLEDE ZA TELOM. V. N. Arkhipov. AN SSSR Dokl., Dec. 1, 1958, pp. 620-622. In Russian. Study of the formation of oscillations in the wake of a moving body. The calculations are made in the second approximation and it is found that the antisymmetric perturbations develop at much lower Reynolds Numbers than the symmetric ones. The obtained results are evaluated in terms of the velocity distribution approaching that of Tollmien's calculations for the case of secondary wakes behind bodies of arbitrary shape. The cross section of the wake with the largest velocity gradient is also considered for the case of stability in the wake of a cylinder. It is shown that the results, derived on the basis of the linear hydrodynamic theory of stability relative to the development of perturbations in the secondary wake, are in fairly good agreement with experimental data on the formation of vortex streets and support the derived hypothesis.

SHOCK GENERATED VORTICITY AND SONIC LINE SLOPE ON THE SURFACE OF BLUNT BODIES IN SUPERSONIC AND HYPERSONIC FLIGHT. S. C. Traugott. Martin Res. Rep. RR 14, Feb., 1959. 34 pp. 12 refs. Derivation of expressions for the inviscid surface vorticity (due to a detached, curved shock) of an arbitrary axisymmetric blunt body at zero incidence, both for a thermally and calorically perfect gas and the real gas effects that appear in the hypersonic region. The vorticity on the surface of a body in an inviscid fluid due to a curved detached shock ahead of the body is found to be inversely proportional to the square of the shock wave vertex radius of curvature. This local vorticity is proportional to the radial distance from the axis of the body and the local pressure in a perfect gas. The surface vorticity is increased within a real gas due to both thermal and caloric gaseous imperfections, as is the surface entropy gradient. Conditions for which the slope of the sonic line is perpendicular to the surface are determined by the use of this vorticity and found to depend on both flight Mach Number and body geometry.

MEASUREMENT OF PRESSURE DISTRIBUTIONS ON AN OSCILLATING WEDGE IN SUPERSONIC FLOW. Appendix - EFFECT OF FLOW DISCONTINUITIES ON PRESSURE MEASUREMENTS. J. R. Martuccelli. MIT ASRL TR 71-2, Oct., 1958. 37 pp. Presentation of a series of pressure distributions over a wedge oscillating in pitch in a two-dimensional supersonic flow for two Mach Numbers (1.4 and 1.8), two surface angles, and three amplitudes of oscillation. In general, the pressure amplitudes lie on or slightly above those predicted by linearized theory, while the phase angles are much lower than the theoretical values. A theoretical investigation is also presented to show that flow discontinuities may be causing significant errors in the pressure measurements.

DISCONTINUITY SURFACES IN MAGNETO-FLUIDYNAMICS. L. G. Napolitano. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 503 (AFOSR TN 59-67) [AD 209842], Dec., 1958. 38 pp. Presentation of a macroscopic study of magneto-fluid-dynamic discontinuities for negligible relativistic effects. Jump conditions relating the end states on the two sides of discontinuity surfaces of arbitrary geometry are derived for both the steady and unsteady cases. Applications are given in connection with (a) the magneto-fluid-dynamic counterpart of the Truesdell-Lighthill-Hayes problem of determining the vorticity jump across the shock, and (b) the existence of magneto-fluid-dynamic slip and/or contact surfaces.

UNDIMENSIONAL MOTION IN MAGNETOHYDRODYNAMICS. G. S. Golitsyn. (Zhurnal Teoret. i Exper. Fiz., Sept., 1958, pp. 776-781.) Sov. Phys. - JETP, Mar., 1959, pp. 538-541. Translation. Investigation of the motion of a perfectly conducting gas in a magnetic field. The Riemann invariants for a number of gases are computed and some nonstationary problems are solved. A new method is proposed for obtaining an approximate general solution of the magnetohydrodynamic equations. A number of problems in which the presence of shock discontinuity plays an essential role are considered in detail.

THE STABILITY OF SHOCK WAVES IN MAGNETOHYDRODYNAMICS. A. I. Akhiezer, G. Ia. Liubarskii, and R. V. Polovin. (Zhurnal Teoret. i Exper. Fiz., Sept., 1958, pp. 731-737) Sov. Phys. - JETP, Mar., 1959, pp. 507-511. Translation. Theoretical determination of the instability of a stationary magnetohydrodynamic shock wave with respect to small perturbations depending only on the distance of the surface of discontinuity and on the time. The method of analysis used is described. It is shown that two types of stable shock waves exist. The types of shock waves that can follow each other are determined.

MAGNETOHYDRODYNAMIC WAVES. J. D. Cole. GALCIT Rep. (AFOSR TN 59-13) [AD 208594], Jan., 1959. 28 pp. Study of shock waves in an infinitely conducting fluid by means of an idealized piston problem. Switch-on waves are shown to be associated with the discharge of a current sheet. The effect of finite conductivity is studied for both ordinary and switch-on waves. It is shown how current sheets are diffused about the wave front. The effects of nonlinearity are discussed in a qualitative way.

SUPERPOSABILITY IN MAGNETOHYDRODYNAMICS. J. N. Kapur. Appl. Sci. Res., Sect. A, No. 2-3, 1959, pp. 198-208. 12 refs. Definition of the concept of additivity and superposability of two hydromagnetic flows. It is shown that force-free fields and self-superposable fluid flows are particular cases of this concept. Chandrasekhar's equations for axially symmetric hydromagnetic flows are extended to viscous fluids, and it is shown that some important results for nonviscous flows need not hold for viscous fluids.

MAGNETOHYDRODYNAMICS AND AERODYNAMIC HEATING. R. X. Meyer. ARS J., Mar., 1959, pp. 187-192. 15 refs. Discussion of the basic equations and of some fundamental concepts of magnetoaerodynamics. The flow near the stagnation point of a body of revolution is reviewed and an exact solution is given. Data are presented for the heat transfer coefficient at the stagnation point and for its gradient in the stagnation point region. The magnetic field strength required to accomplish an appreciable reduction of aerodynamic heating in hypersonic flight is discussed for the case in which ionization is due to thermal motion. Methods involving electrical breakdown of the air are considered.

THE TRANSMISSION OF ELECTROMAGNETIC WAVES IN THE PRESENCE OF A CONDUCTING LAYER OF GAS. G. S. S. Ludford. U. Md. Inst. Fluid Dynamics & Appl. Math. TN BN-160 (AFOSR TN 59-159) [AD 211118], Feb., 1959. 22 pp. Study of two related problems in electromagnetic wave transmission. (1) The reflection and transmission of plane waves at a perfectly conducting layer of gas in an otherwise nonconducting atmosphere, when there is a uniform external magnetic field perpendicular to the layer present. The main result is that a layer of finite depth h is an almost perfect filter, being transparent to waves of frequency $(n\ \pi A_o)/h$ (A_o = Alfven velocity, n an integer). (2) The existence of plane surface waves for such a finite layer. There is always one such wave and, for certain ranges of frequency, two. The first becomes "choked" at the filter frequencies, its velocity first tending to zero and then jumping to a finite value. The second chokes at the frequencies $(n\ \pi\ A_o\ a_o)/h\ \sqrt{a_o^2 + A_o^2}$ (a_o = acoustic velocity).

THE FLOW OF CHEMICALLY REACTING GAS MIXTURES. J. F. Clarke. Coll. of Aeronautics, Cranfield, Rep. 117, Nov., 1958. 28 pp. 10 refs. Derivation of equations for the flow of an inviscid, non-heat-conducting gas with chemical reactions, neglecting transport processes. The speeds of sound in such a gas mixture are considered, and a general expression for the ratio of frozen to equilibrium sound speeds is deduced. The significance of the velocity defined by the ratio of the convective derivatives of pressure and density is explained. It is the velocity which exists at the throat of a convergent-divergent duct under maximum mass flow conditions, and it is shown that this velocity depends on the nozzle geometry as well as on the "reservoir" conditions. The phenomena of sound absorption and dispersion are discussed for the ideal dissociating gas. The results can be concisely expressed in terms of the frozen and equilibrium sound speeds, the frequency of the (harmonic) sound vibration, and a characteristic time for the rate of progress of the reaction.

CHEMICALLY FROZEN BOUNDARY LAYERS WITH CATALYTIC SURFACE REACTION. D. E. Rosner. J. Aero/Space Sci., May, 1959, pp. 281-286. 13 refs. Development of a simple approximate method for studying the streamwise distribution of reaction rate in terms of the shear and temperature distributions along the surface. The method is based upon a treatment of the concentration integral equation which initially parallels Liepmann's treatment of the energy integral equation, but which ultimately leads to a differential equation for the concentration distribution of reactant along the surface. The hydrodynamic field is unaltered by the surface reaction, and only the effect of small surface temperature differences on the kinetics of the wall reaction - i.e., the effective "sink" strength - are taken into account. Extension to the case of several reactants is discussed, and an interpretation of the governing catalytic parameter as a ratio of characteristic times is given.

THE "PUNCH" METHOD OF COMPRESSING, HEATING AND CONFINING OF A PLASMA. H. G. Loos. Plasmadyne Corp. TN T-1TN128-335 (AFOSR TN 58-1130) [AD 207975], Dec., 1958. 25 pp. 10 refs. Study of a method for compressing, heating, and confining of a plasma by means of a suddenly applied magnetic field of external origin. The basic cylindrical configuration does not show any instabilities in the hydrodynamic approximation. The number N_i of ions per unit length along the tube is shown to be related to the amount of separation between plasma and field that is achieved in times small compared with the decay time of the field. Furthermore, this number N_i determines how many large angle collisions an ion will undergo with other ions during the decay time. Order of magnitude calculations have been made of the energy required for heating by isentropic compression and of the energy and voltage required for shock heating.

THERMODYNAMIC FOUNDATION OF THE THEORY OF PLASMA. Taro Kihara. Phys. Soc. Japan J., Feb., 1959, pp. 128-133. 14 refs. Application of the thermodynamics of irreversible processes to dense plasmas in a weak magnetic

field. A plasma composed of several species of charged and neutral particles is considered, in which neither ionization nor recombination occurs and no temperature difference exists between plasma components. Basic equations of magneto-thermo-hydrodynamics are derived together with relations between transport coefficients. Extremely dilute plasmas and plasmas at the Debye-Hückel limit are discussed as particular cases.

EXPLORATORY EXPERIMENTAL STUDY OF A NEW METHOD OF ENERGY EXCHANGE BETWEEN STEADY FLOWS. W. J. Guman. Rensselaer Polytech. Inst. Res. Div. TR AE 5811 (AFOSR TN 59-14) [AD 208595], May, 1958. 56 pp. Investigation on an energy transfer mode set forth by Foa, concerning radial-flow air-to-air induction by pseudo-blades in free-rotor models. Test results showing the effects of various gasdynamic and geometrical parameters are presented, and results of limited flow visualization studies are discussed.

THE INTERACTION OF A PLANE SHOCK WAVE WITH AN INCLINED PERFORATED PLATE. W. H. Friend. UTIA TN 25, Oct., 1958. 69 pp. 27 refs. Experimental investigation conducted in a shock tube with the two-dimensional interaction being recorded on shadow and schlieren photographs. Weak incident shock waves produced two main wave elements - the reflected and transmitted shock waves - and a turbulent contact surface. Strong incident shock waves caused choked flow at the minimum plate cross section, and a supersonic region downstream of the plate terminated by an additional travelling shock wave. The calculated results for the transmitted, reflected, and auxiliary shock strengths and their inclinations, as well as the predicted critical flow choking Mach Number and contact front inclination, are in good agreement with the experimental results.

STRUCTURE OF SHOCK FRONTS IN IONIZED GASES. Max Krook. Ann. Phys., Feb., 1959, pp. 188-207. Presentation of a method for the solution of the kinetic equations for the structure of a shock wave in an ionized gas. In an approximation of order ν, the kinetic equations are replaced by a set of $(\nu - 4)$ equations for moments of the velocity distribution. The procedure is based on a representation of the distribution functions as sums of "modified Maxwell functions."

AFTERGLOW INVESTIGATIONS OF SHOCK DETACHMENT DISTANCES AT LOW REYNOLDS NUMBERS. E. S. Moulic. USAF WADC TR 57-643 [AD 155795], July 15, 1958. 53 pp. 11 refs. Determination of the shock detachment distances for blunt bodies in the range $1.8 < M < 2.8$ and $100 < Re/in. < 1,200$, using an air afterglow flow visualization apparatus and free molecule probe. Cylindrical models were used to develop the experimental techniques and reasonable agreement is shown between detachment distances measured by afterglow and free molecule probe techniques. Spherical model detachment distances were obtained by the afterglow technique and, when corrected for boundary layer effects, showed satisfactory agreement with the predictions of Heybey, provided isentropic flow existed between the shock wave and the boundary layer. It is shown that shock detachment distances in rarefied gas flows depend on both Mach and Reynolds Numbers.

ON THE FLOW OF GASES UNDER NEARLY FREE MOLECULAR CONDITIONS. D. R. Willis. Princeton U. Dept. Aero. Eng. Rep. 442 (AFOSR TN 58-1093) [AD 207594], Dec., 1958. 21 refs. Study of several methods for obtaining the correct solution to the problem of linearized Couette flow. The Boltzmann equation is transformed into an integral equation, and an iterative method of solving for the distribution function is proposed. If the iteration commences with the free molecular distribution function, it appears that one iteration is sufficient to give the distribution function for nearly free molecular conditions. The method of first collisions is shown to be an approximate method of calculating this iterate. It is valid when the free stream Mach Number is high and the body temperature is comparable to the free stream stagnation temperature. The method is applied to various geometries and results presented for the corrections to the free molecular macroscopic quantities at the body.

A UNIFIED THEORY OF TURBULENT FLOW. I - FORMULATION OF THE THEORY. William Squire. Appl. Sci. Res., Sect. A, No. 2-3, 1959, pp. 158-168. 18 refs. Critical analysis of the assumptions underlying Reynolds' equations of turbulent flow. It is shown that there are regions in a flow field where these assumptions break down, and it is therefore necessary to separate the flow into a turbulent core and a laminar sublayer. A set of equations for calculating turbulent flows is proposed, and the turbulent stresses are represented as the difference between viscous terms with a large eddy viscosity and terms satisfying auxiliary differential equations proposed by Broszko. The theory enables the idea of a large eddy viscosity to be applied even for large velocity gradients. The results obtained for specific configurations are presented.

ON THE THEORY OF HOMOGENEOUS AXISYMMETRIC TURBULENCE. Michio Ohji. Kyushu U. Rep. Res. Inst. Appl. Mech., No. 22, 1958, pp. 63-83. Development of basic expressions and equations of homogeneous axisymmetric turbulence, where the axisymmetric spectrum tensors are introduced. The explicit representation of the second- and third-order wave-number tensors together with the governing dynamic equations is shown. Defining the special types of axisymmetric turbulence - i.e., quasi-isotropic, axial and transverse turbulence, it is indicated how to interpret the general axisymmetric case as a composition of these elementary fields of motion.

THE EFFECT OF UNIFORM DISTORTION ON WEAK HOMOGENEOUS TURBULENCE. J. R. A. Pearson. J. Fluid Mech., Feb., 1959, pp. 274-

288. Analysis of the behavior of turbulence, by means of linearized equations that include the effect of inertial interaction between the mean flow and the turbulent fluctuations, and of the viscous dissipation. Three particular cases of distortion are investigated: uniform rotation, uniform shear, and uniform irrotational distortion. For the first two, the total energy associated with the turbulence is found to decay, but for the third it is found in general to increase without limit. A general solution is given in terms of the spectrum functions for the restricted case of irrotational distortions.

WALL TURBULENCE. Carlo Ferrari. (Internatl. Cen. Math. Summer Studies, Varenna, Sept. 1-10, 1957.) US, NASA RE 2-8-59W, Mar., 1959. 133 pp. 22 refs. Translation. Theoretical study of the factors affecting the development of a turbulent flow in the presence of a solid wall in order to obtain a better understanding of the problem. The governing flow relationships are used to study some simple cases of wall turbulence, such as a flat plate with or without a uniform pressure gradient or flow in a uniform channel. Some simplifying asumptions are made. A brief discussion of other theories is presented in an attempt to arrive at a rational theory of wall turbulence.

A THEORY OF HOMOGENEOUS ISOTROPIC TURBULENCE. P. C. Jain. Appl. Sci. Res., Sect. A, No. 2-3, 1959, pp. 219-227. 10 refs. Tentative definition of a simplifying hypothesis for connecting the higher order correlation tensor with the lower ones. Starting from the Navier-Stokes equation of motion for an incompressible fluid and the equation of continuity, the basic differential equation is derived by following the usual method of taking averages. Then, using Kolmogoroff's hypothesis, two different results are obtained.

Internal Flow

THE MIXING OF UNBOUNDED CO-AXIAL COMPRESSIBLE STREAMS. D. R. Willis and Irvin Glassman. James Forrestal Res. Cen., Squid TR PR-70-P[AD146039], Nov., 1957. 34 pp. (Microtext.) Investigation of unbounded compressible axisymmetric mixing, where clean exit conditions allow significant measurements to be taken in the core region. Total pressure and, where applicable, total temperature measurements are taken for various combinations of primary Mach Numbers (M_1) of 2.60, 0.97, and 0.68; secondary Mach Numbers (M_a) of 0.45, 0.25, and 0.00; and stagnation temperature ratios of 1.00 and 1.429. Mass flows in the mixing region, and hence mixing rates, are computed from experimental data. Results show a marked effect of M_a for subsonic M_1. Overall spreading is less for $M_1 = 2.60$ and the effect of M_a is less pronounced.

Jet Flap & Wings

A THEORY OF THE JET FLAP IN THREE DIMENSIONS. E. C. Maskell and D. A. Spence. Gt. Brit., RAE Rep. Aero. 2612, Sept., 1958. Development of a lifting-surface theory for a wing of finite span with a full-span jet flap emerging from its trailing edge with a small angular deflection τ. The downwash equation and boundary conditions governing the flow are derived, assuming the lifting surface lines in $z = 0$, where the boundary conditions are satisfied, and neglecting transverse transport of momentum within the jet. The results are compared with experimental data obtained with an 8:1 elliptic cylinder of rectangular plan form and aspect ratios of 2.75, 6.8, and infinity.

DESIGN STUDY OF A MODIFIED HIGH LIFT AND LATERAL CONTROL SYSTEM FOR THE L-21 AIRPLANE. W. S. Childress. Princeton U. Dept. Aero. Eng. Rep. 422, July, 1958. 21 pp. 12 refs. Army-Navy-supported study of spoiler type lateral controls as a means of utilizing full span flaps. An air jet spoiler is described which eliminates some of the response problems associated with mechanical spoilers, along with a high lift system utilizing this device in conjunction with moderate BLC equipment. Preliminary calculations are carried out for this system as applied to the L-21 (PA-18) aircraft. For boundary layer blowing over the inboard flap and simultaneous application of full spoiler, the power supply is found to be adequate as an air source. The modified aircraft has a calculated $C_{L_{max}}$ of 2.98 using the stock engine, but requires additional longitudinal trim during landing sufficient to change the effective incidence of the tail -11.5°.

Stability & Control

LOW-SUBSONIC STATIC STABILITY AND DAMPING DERIVATIVES AT ANGLES OF ATTACK FROM 0° TO 90° FOR A MODEL WITH A LOW-ASPECT-RATIO UNSWEPT WING AND TWO DIFFERENT FUSELAGE FOREBODIES. P. C. Boisseau. US, NASA Memo. 1-22-59L, Mar., 1959. 25 pp. Investigation on models having a long pointed nose and a shorter rounded nose in the Langley free-flight tunnel to determine the static stability, control effectiveness, and damping in roll and yaw. Although the wing stalled at an angle of attack of about 12°, maximum lift did not occur until an angle of attack of about 40° or 50° was obtained. The static longitudinal stability of the model having a short rounded nose was greater than that of the model having a longer pointed nose over the entire angle-of-attack range. The pointed-nose model had large out-of-trim yawing moments above an angle of attack of about 40°. Shortening and rounding the nose of the model delayed these out-of-trim yawing moments to slightly higher angles of attack. Both models were directionally unstable above an angle of attack of about 20°, but both had positive effective dihedral over virtually the entire angle-of-attack range.

NOTE ON A CRITERION FOR SEVERITY OF ROLL-INDUCED INSTABILITY. O. B. Gates and Karlis Minka. J. Aero/Space Sci., May, 1959, pp. 287-290. Presentation of a method which may be used to evaluate the severity of the roll-induced instability inherent in many current aircraft designs. The analysis is based on the assumption of

a steady rolling velocity and, for this case, expressions are presented from which the divergence rates can be estimated. Also, from the knowledge of the divergence rates, the magnitude of the divergence may be estimated as a function of the angle through which the aircraft is rolled.

SOME EFFECTS OF YAW DAMPING ON AIRPLANE MOTIONS AND VERTICAL-TAIL LOADS IN TURBULENT AIR. Jack Funk and T. V. Cooney. US, NASA Memo. 2-17-59L, Mar., 1959. 8 pp. Presentation of results of analytical and flight investigations on yaw damping effects. The analytical studies indicate a rapid reduction in loads on the vertical tail as the damping is increased up to the point of damping the lateral motions to 1/2 amplitude in one cycle. Little reduction in load is obtained by increasing the lateral damping beyond that point. Flight measurements indicate that a yaw damper reduces the loads on the vertical tail due to turbulent air and that the pilot can provide a significant amount of lateral damping.

Wings & Airfoils

ON THE EXISTENCE OF INFINITE ACCELERATION POINTS IN TRANSONIC FLOWS AROUND AIRFOILS WITH FINITE CURVATURE. Silvio Nocilla. Torino Polytech. Inst. Appl. Mech. Lab. TN 11 (AFOSR TN 59-197) [AD 211474], Dec., 1958. 17 pp. Analysis concerning the formation of shock waves around airfoils. Assumed as a suitable criterion for the theoretical interpretation of the appearance of such a shock wave is the appearance of a point with infinite acceleration on the physical plane. The conditions which must be fulfilled on the hodograph plane in order that such a point exists, and the properties which the corresponding stream function must possess, are studied and then applied to airfoils of constant curvature.

PRESSURE DISTRIBUTION AT THE NOSE OF A THIN LIFTING AIRFOIL. Anatol Roshko. Douglas Rep. SM-23368, Nov., 1958. 27 pp. Derivation of single expressions for the pressure distribution at the nose of a lifting symmetrical airfoil by comparison with a simpler airfoil consisting of an ellipse with a fin. The expressions compare favorably with measurements and exact calculations of pressure distributions on several thin airfoils.

THE CENTRE SECTION SHAPE OF SWEPT TAPERED WINGS WITH A LINEAR CHORDWISE LOAD DISTRIBUTION. J. C. Cooke. Gt. Brit., RAE TN Aero. 2584, Sept., 1958. 29 pp. Application of the method of Weber to find the shape of the center section of a swept tapered wing to produce a load distribution which changes linearly from unity at the leading edge to zero at the trailing edge along any chord. An approximation for this distribution is used in order to make the integrals more tractable, and the integrals are then evaluated. A reasonably accurate approximate formula for the downwash is derived, and the results are illustrated by a few examples, giving downwash and angles of twist.

EXPERIMENTS WITH A TWO-DIMENSIONAL AEROFOIL DESIGNED TO BE FREE FROM TURBULENT BOUNDARY-LAYER SEPARATION AT SMALL ANGLES OF INCIDENCE FOR ALL MACH NUMBERS. D. W. Holder and R. F. Cash. Gt. Brit., ARC R&M 3100, 1959. 49 pp. 16 refs. BIS, New York, $3.15. Investigation to check the validity of a simple method of airfoil design and study of the transonic flow past the airfoil. The results are compared with previous speculations concerning the nature of the flow when separation is absent. For large angles of incidence the flow with separation and the effects of separation are considered. A discussion of the results shows that the value of the flow deflection angle at the trailing edge determines whether shock-induced separation occurs at transonic speeds.

10 ft. x 7 ft. HIGH SPEED TUNNEL TESTS OF THE EFFECTS OF COMBINED NOSE DROOP AND OUTER-WING CHORD EXTENSIONS ON A 7 1/2 p.c. THICK 50° SWEPT WING. A. L. Courtney. Gt. Brit., RAE TN Aero. 2585, Sept., 1958. 31 pp. Investigation using a swept wing with the object of improving the longitudinal stability characteristics (pitch up) at subsonic speeds with moderate and high lift coefficients. Lift, drag, pitching moment, and root bending moment are measured at Mach Numbers up to 0.94. At low Mach Numbers the combination of full-span droop with outer-wing chord extension is highly advantageous, giving no appreciable loss of stability up to the highest test lift coefficient of 1.22. At high speeds, however, the advantages are fairly small and the usuable C_L is no greated than for the part-span droop arrangement tested earlier. The discontinuous chord-extension is beneficial at all Mach Numbers, and it is thought that a combination of chord extension and nose droop without the thickening should give better high-speed characteristics than any so far achieved on this wing, although at some cost in low-speed characteristics compared with the thick droop tested.

AN ESTIMATE OF THE SUCTION PEAK ON INFINITE SHEARED WINGS. J. Weber. Gt. Brit., RAE TN Aero. 2587, Oct., 1958. 5 pp. Derivation of a simple relation between the minimum pressure coefficient and the nose radius. The value of the suction peak near the nose in incompressible flow depends primarily on the value of the lift coefficient and the nose radius and not on the angle of sweep.

ON THE AERODYNAMIC DESIGN OF SLENDER WINGS. E. C. Maskell and J. Weber. Gt. Brit., RAE Rep. Aero. 2610, Aug., 1958. 36 pp. 19 refs. Study of the aerodynamic design of slender pointed wings with sharp edges, under the condition that flow separation from these edges dominates the flow pattern in all flight attitudes. The study includes a particular class of doubly curved mean surfaces satisfying the leading-edge condition, onto which thickness distributions are superposed so as to provide favorable velocity fields together with low drag. Some examples are given, using slender-thin-wing theory for flexibility, in order to illus-

trate the manner in which plan form and thickness distributions affect the pressure distribution, and to indicate the relatively high lift-drag ratios which seem feasible. The limitations of the theory employed and further developments are also considered.

EXPERIMENTAL INVESTIGATION OF AERODYNAMIC EFFECTS OF EXTERNAL COMBUSTION IN AIRSTREAM BELOW TWO-DIMENSIONAL SUPERSONIC WING AT MACH 2.5 AND 3.0. R. G. Dorsch, J. S. Serafini, E. A. Fletcher, and I. I. Pinkel. US, NASA Memo. 1-11-59E, Mar., 1959. 19 pp. Determination of the pressure distributions associated with stable combustion of aluminum borohydride in the air stream adjacent to the lower surface of a 13-in. chord, two-dimensional, blunt-base wing. The measurements were made with the wing at a 2° angle of attack in 1-ft. x 1-ft. tunnel. Static-pressure increases along the lower surface and base caused by the combustion are presented along with the resultant lift increases. The lift and drag of the wing during combustion are computed from the pressure data and compared with the nonburning values. The measured lift coefficients agree with those calculated analytically.

THE EFFECT OF MOMENT-OF-AREA-RULE MODIFICATIONS ON THE DRAG, LIFT, AND PITCHING-MOMENT CHARACTERISTICS OF AN UNSWEPT ASPECT-RATIO-6 WING AND BODY COMBINATION. R. R. Dickey. US, NASA Memo. 2-24-59A, Mar., 1959. 29 pp. Investigation on a model with full moment-of-area-rule modifications having four contoured pods mounted on the wing and indentations in the body to improve the longitudinal distributions of area and moments of area. Also investigated are modifications employing pods and indentations that are only half the size of the full modifications. Tests are made at angles of attack from -2° to +12° at Mach Numbers from 0.6 to 1.4. The minimum drag of a wing-body combination is substantially reduced in the transonic and low supersonic speed range by means of moment-of-area-rule modifications which improved the distribution of the area and the second and fourth moments of area. However, the modifications resulted in increased drag at subsonic speeds. Near Mach Number 1.0, the full moment-of-area-rule design resulted in the lowest drag, but at higher speeds (1.06 to 1.40) the design employing half-size modifications has the lowest drag. Partial modifications which did not indent the body to compensate for cross-sectional area of the pods generally resulted in smaller drag reductions.

FAVORABLE INTERFERENCE OF A BODY AND BIPLANE COMBINATION IN SUPERSONIC FLOW. Lu Ting. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 510 (AFOSR TN 59-200) [AD 211526], Mar., 1959. 10 pp. Comparison of an optimum contoured prismatic body mounted on a triangular midwing with a combination of the same body and a biplane arrangement of a triangular high wing and low wing. For the same lifting surface, the span of the wings of the second combination is one-half that of the midwing. The second configuration is shown to be favorable from the structural and aerodynamic aspects. Special configurations considered in a numerical example indicate a reduction of 8% in drag for the same lift in the biplane-body combination as compared with the monoplane-body combination.

AEROELASTICITY

SMALL ASPECT RATIO MEMBRANE FLUTTER. Appendix A - THEORETICAL FORMULATION OF THE SLENDER MEMBRANE FLUTTER PROBLEM. Appendix B - DETERMINATION OF THE MINIMUM EIGENVALUE. Ronald Stearman. GALCIT Rep. 1 (AFOSR TR 59-45) [AD 209415], Jan., 1959. 46 pp. 19 refs. Investigation of flutter on rectangular membranes in subsonic flow having leading and trailing edges restrained from vertical movement. The results show that two types of flutter occur. The first to appear as the wind speed is increased from zero, with a fixed tension level in the membrane, was a small amplitude flutter which had a shallow wave-like motion traveling in the streamwise direction. At higher wind speeds this motion was damped out. A narrow equilibrium zone or boundary existed which separated the first type of flutter from a second type of motion having a traveling wave of layer amplitude and greater speed. This second type of flutter had no tendency to damp out, but became more violent as the wind speed was increased. The span of the slender membrane is the physical parameter that uniquely determines and controls the first flutter boundary; its mass plays no part here, but does affect the equilibrium zones.

A THEORETICAL TREATMENT OF THE FLUTTER OF A WING WITH A LOCALISED MASS. D. R. Gaukroger. RAeS J., Feb., 1959, pp. 95-103. Flutter calculations on a fixed root wing using modes based upon artificial restraints at the localized mass section. Good agreement between calculations and experimental results justifies the extension of the calculations to conditions of localized mass loading not covered by experiment. The extended calculations show that there is an optimum spanwise position for a localized mass and that it is related to the nodal line position in the overtone torsion mode of the bare wing. For values of localized mass parameters likely to occur in practice, flutter speeds can be estimated from calculations in a very limited number of modes.

A THEORY OF THE RESPONSE OF AIRPLANES TO RANDOM ATMOSPHERIC TURBULENCE. B. Etkin. UTIA Rep. 54, May, 1958. 34 pp. Analysis utilizing Ribner's formulation for the turbulence, but dealing only with the vertical component of the gust velocity. The method is based upon the approximation of a single spectral component of the turbulent downwash by a modified two-dimensional Taylor series in the neighborhood of the aircraft. It is found that only terms up to the second degree are necessary to obtain a good fit for wave lengths down to twice the relevant airplane

dimensions. The final expressions give the forces and moments in terms of a set of aerodynamic derivatives such as those used in stability and flutter analysis.

EVALUATION OF SEVERAL APPROXIMATE METHODS FOR CALCULATING THE SYMMETRICAL BENDING-MOMENT RESPONSE OF FLEXIBLE AIRPLANES TO ISOTROPIC ATMOSPHERIC TURBULENCE. F. V. Bennett and R. T. Yntema. US, NASA Memo. 2-18-59L, Mar., 1959. 57 pp. Evaluation of two modal and one matrix methods. The approximate procedures are applied to a simplified aircraft, consisting of a uniform beam with a concentrated fuselage mass at the center, for which an exact solution to the equation of motion can be obtained. The force-summation and the matrix methods are shown to give satisfactory accuracy, whereas the mode-displacement method does not. The effects of spanwise variations of vertical gust velocity are also studied.

ZUSAMMENFASSENDER BERICHT ÜBER NEUERE UNTERSUCHUNGEN ZUR FRAGE DER BÖENBELASTUNG VON FLUGZEUGEN. H. Krumhaar. Max-Planck-Inst. Strömungsforsch. Mitteil. No. 21, 1958. 143 pp. 117 refs. DM 13. In German. Review of recent investigations on the problem of gust loading of aircraft. The usual method of calculation for various forms of single gusts is considered and the stress due the atmospheric turbulence is examined, using the concept of an energy spectrum. Partial comparison with results obtained by the single-gust method shows that there is considerable qualitative agreement, but the latter method omits many effects which occur in complex gust loading.

ON AXISYMMETRIC VIBRATIONS OF THIN SHALLOW VISCOELASTIC SPHERICAL SHELLS. P. M. Naghdi and W. C. Orthwein. U. Mich. Res. Inst. TN 5 (AFOSR TN 59-109) [AD 210389], Jan., 1959. 27 pp. 16 refs. Analysis covering transverse vibrations of shallow viscoelastic spherical shells subjected to axisymmetric loads which are harmonic in time. In particular, the steady state solution is obtained for an unlimited viscoelastic shallow shell subjected to an oscillating load uniformly distributed over a small circular region about the apex. Numerical results for axial displacement and stresses are obtained for two special viscoelastic media (Maxwell and Kelvin) as well as for the elastic shell, and comparison is made with known results.

VIBRATIONS AND STABILITY OF PLATES UNDER INITIAL STRESS. G. Herrmann and A. Armenakas. Columbia U. Inst. Flight Struc. Rep. (AFOSR TN 59-189) [AD 211220], Feb., 1959. 52 pp. 14 refs. Establishment of several linear theories of motion for elastic plates taking initial moments and transverse shear forces into account in addition to initial membrane forces. The equations of motion are obtained by linearizing the appropriate nonlinear plate equations and reduced to either the classical or the Mindlin plate theory. These equations are applied to the solution of particular problems, and the effect of uniform initial compression, bending moment, and transverse shear force on the frequencies of the flexural, longitudinal, thickness-shear and the first two face-shear modes is discussed.

VIBRATIONS OF BEAMS. III - SCREW MODES. W. A. Green. Quart. J. Mech. & Appl. Math., Feb., 1959, pp. 22-28. 13 refs. Solution of the exact equations of wave propagation in an elastic medium to obtain the dispersion equation for screw vibrations of a circular cylinder. Dispersion curves are obtained for the fundamental mode, for a range of values of the Poisson ratio, in the long and intermediate wavelength region, and the crossovers of these curves and the corresponding curves for the longitudinal form of motion determined.

AIRPLANES

Landing Gear

LANDING-GEAR VIBRATION INSTABILITY. F. L. Ryder and Melvin Zaid. J. Aero/Space Sci., May, 1959, pp. 303-309, 320. Presentation of a theory of gear walking or excessive vibration of the landing gear during the landing run which attempts to isolate the essential physical parameters and to derive the differential equations which must be satisfied by the resulting idealized model of the aircraft. It is found that if the curve of wheel-braking torque versus angular velocity has a negative slope under conditions of rapid variation of the angular velocity, then the model will be unstable below a certain critical aircraft speed. If, on the other hand, the slope of the curve is zero or positive, then the model has a definite margin of stability, so that gear walking can occur only if the braking torque repeatedly exceeds the skidding value. A detailed study is made of the behavior under sinusoidal disturbances for the purpose of gaining a physical understanding of the phenomenon, and remedial measures are discussed briefly.

MATERIALS

Metals & Alloys

ON STRESS INTERACTION IN FATIGUE AND A CUMULATIVE DAMAGE RULE. I - 2024 ALUMINUM AND SAE 4340 STEEL ALLOYS. A. M. Freudenthal and R. A. Heller. USAF WADC TR 58-69, Pt. I [AD 155687], June, 1958. 48 pp. 36 refs. Investigation to determine the effects of stress-interaction on the fatigue life of smooth aluminum and steel specimens, while under randomly varied exponentially distributed stress amplitudes representing gust and maneuver loads on aircraft wings. A quasi-linear rule of cumulative damage is developed on the basis of stress-interaction factors and a fictitious S-N diagram produced by such an interaction. Random fatigue tests with exponential spectra confirm the theory. The damaging effect of low stress amplitudes when mixed with infrequent high amplitudes is demonstrated. In steel this effect eliminates the conventional endurance limit as a significant design value under varying stress amplitudes.

GRAIN SIZE EFFECTS ON FATIGUE AND THEIR RELATIONSHIP TO NOTCH GEOMETRY, STRESS GRADIENT AND SIZE OF SPECIMENS. F. H. Vitovec. USAF WADC TR 58-539 [AD 206665], Dec., 1958. 32 pp. 17 refs. Presentation of results on the direct stress fatigue of 2.5 Al-Mg alloy in three different grain sizes, using specimens with seven different notch sizes. The data are analyzed with regard to relationships between grain size, size of notch, relative stress gradient, stress gradient per grain, and theoretical strength of notched specimens.

Nonmetallic Materials

NOTE ON THE COMPRESSIVE AND BENDING STRENGTH OF FIBERGLASS REINFORCED PLASTIC PLATES. Appendix - THE EQUILIBRIUM OF ONE GLASS FIBER AND PLASTIC LAYER. J. P. Benthem. Netherlands, NLL TN S.531, Oct. 13, 1958. 29 pp. Study of a simplified model consisting of many thin layers, alternately of glass and plastic, which show a wave form in order to give an explanation of the fact that above a certain glass percentage the compressive strength does not increase with the glass percentage and that the bending stress at failure increases with decreasing thickness. It is confirmed that the ultimate bending stress of thin fiberglass reinforced plastic plates is higher than the ultimate compressive stress. This is due to the stabilizing effect of the tension layers on the compressive layers which becomes more pronounced on thinner plates.

MATHEMATICS

SPECIAL ISSUE: ACTES DES COLLOQUES DE CALCUL NUMERIQUE. (AFAS 74th & 75th Congr., Caen, 1955; Dijon, 1956.) France, Min. de l'Air NT 77, 1958. 144 pp. 72 refs. SDIT, 2 Av. Porte-d'Issy, Paris 15, Frs. 2,105. In French. Contents: L'Estimation de la Part du Hasard, M. Kiveliovitch. Interprétation Statistique de la Fatigue, E. J. Gumbel. Sur un Lissage par Moyenne, de Relevés Expérimentaux Très Aberrants, n'Introduisant Pas de Périodicité Fictive, P. Vernotte. Quasi-Dérivée, A. Martinot-Lagarde. Sur une Interprétation Expérimentale de la Dérivée, A. Martinot-Lagarde. Théorie et Réglage de l'Equatorial, S. Arend. Calcul de la Valeur Numérique de la Dérivée Seconde, pour une Valeur de la Variable, d'une Fonction Donnée par des Valeurs non Equidistantes, A. Ziller. Le Problème Géométrique du Rattachement d'un Astre à n Etoiles de Référence, Basé sur le Principe de l'Homographie Linéaire, S. Arend. A Propos des Notations Différentielles en Physique Mathématique, P. Vernotte. Sur un Procédé de Capture des Racines des Equations Algébriques, R. Eybert. Résolution Rapide des Systèmes d'Equations Linéaires, R. Gouarné. Compilation of eleven papers on the numerical calculation covering: the role of chance; statistical interpretation of fatigue; arrangement of scattered experimental results without introducing a fictional periodicity; the quasi-derivative; experimental interpretation of the derivative; theory and control of the equatorial; calculation of the numerical value of the second derivative for a function given by nonequidistant values; geometrical problem of the reattachment of an asteroid to n-reference stars, based on the principle of linear homography; differential notations in physical mathematics; a capture process for the roots of algebraic equations; and a rapid solution for systems of linear equations.

MISSILES

FLIGHT MECHANICS OF LOW-THRUST SPACE CRAFT. F. M. Perkins. J. Aero/Space Sci., May, 1959, pp. 291-297. Analysis of low-thrust space trajectories in order to eliminate or at least reduce the amount of digital machine trajectory computation required for performance studies. For spacecraft using constant thrust acceleration, parameters are presented for generalizing all differential equations of motion to make them independent of the thrust acceleration and the gravity constant (choice of planet). In the case where this thrust is directed tangentially throughout flight, generalized plots are presented relating velocity, radius distance, and time. When the constant tangential thrust acceleration is less than 10^{-2} initial g, single curves independent of the value of the thrust acceleration result, relating the parametric velocity, radius distance, and time.

ON THE FLIGHT PATH OF A HYPERVELOCITY GLIDER. Angelo Miele. Purdue U. Sch. Aero. Eng. Rep. A-59-2, Jan., 1959. 34 pp. Army-supported investigation of the flight of a hypervelocity vehicle operating along a so-called equilibrium trajectory - i.e., a trajectory such that the weight is balanced by the lift plus the centrifugal force due to the curvature of the earth. By means of the calculus of variations it is shown that the path which maximizes the range includes: an initial subarc in which all the propellant mass is expended at the maximum burning rate of the engine; and a final subarc in which the hypersonic glider coasts at variable altitude and in such a way that, for each instantaneous velocity, the aerodynamic drag is a minimum. No variable thrust subarc appears in the composition of the extremal arc. It is concluded that the solution previously indicated by Eggers, Allen, and Neice is an extremal trajectory (a path consistent with the Euler equations) with regard to both the programing of the angle of attack and the burning program.

AN INVESTIGATION OF THE PERFORMANCE OF VARIOUS REACTION CONTROL DEVICES. P. A. Hunter. US, NASA Memo. 2-11-59L, Mar., 1959. 37 pp. Investigation made in still air utilizing both subsonic and supersonic internal flows. The range of nozzle total-exit-pressure ratios covered was from approximately 1.3 to 6.5. The specific parameters investigated are the ratio of lateral force to resultant force of the undeflected jet, the ratio of resultant force to resultant force of the undeflected jet, and the ratio of weight flow referred to the weight flow of the undeflected jet.

APPLICATION OF ASTRONOMICAL PERTURBATION TECHNIQUES TO THE RETURN OF

SPACE VEHICLES. R. M. L. Baker, Jr. ARS J., Mar., 1959, pp. 207-211. 12 refs. Application of perturbation techniques, which increase the accuracy of the computations and shorten the computational times required, to the return of space vehicles from satellite, lunar, and interplanetary missions. The proposed variation-of-parameters perturbation method is illustrated by applying it to the problem of a gravitational orbit perturbed by drag and to the inverse problem of a gravity-free drag orbit perturbed by gravity. Comparative calculations indicate that the perturbation computations are 3 to 10 times faster and 11 to 165 times more accurate than the nonperturbation computations.

NUCLEAR ENERGY

PERFORMANCE CALCULATIONS FOR HYBRID NUCLEAR-CHEMICAL ROCKET PROPULSION SYSTEMS. Leon Green, Jr., and J. M. Carter. (ARS Spring Meeting, Dallas, Mar., 1958.) ARS J., Mar., 1959, pp. 180-186. 24 refs. Presentation of preliminary performance calculations for chemical propellant systems consisting of water and light metals, assuming preheat by an external source, such as a nuclear reactor, to vaporize the propellants and thus permit the generation of products with high available enthalpy in the ensuing combustion. The possible advantages over conventional chemical and nuclear propulsion systems to be derived by use of the hybrid nuclear-chemical system are described. A qualitative discussion of the engineering difficulties faced by the various nuclear systems is made.

LES MATERIAUX NUCLEAIRES SOLIDES COMME CONSTITUANTS DES SYSTEMES PROPULSIFS. J. A. Ternisien. Fusées, No. 3, 1958, pp. 127-142. 19 refs. In French. Study covering solid nuclear materials as constituents of propulsion systems. Three groups are considered: (a) combustible or fissile material, (b) structural materials, and (c) cooling materials. The behavior of some pure metals absorbent at hight temperatures, metals and alloys with slight absorption, metalloids and ceramics, as well as cermets are examined in terms of anticipated requirements of fabrication and use. Such factors as the resistance to corrosive agents and magnetic and physical properties are also included.

PHYSICS

STRUKTURA I DVIZHENIIA KRUPNYKH NEODNORODNOSTEI V IONOSFERNOM SLOE F_2. V. D. Gusev, L. A. Drachev, S. F. Mirkotan, Iu. V. Berezin, M. P. Kiianovskii, M. B. Vinogradova, and T. A. Gailit. AN SSSR Dokl., Dec. 11, 1958, pp. 817-820. In Russian. Investigation of the structure and motions of large inhomogeneities in the F_2 layer of the ionosphere. An accurate integral method for recording these phenomena is developed providing a statistical approach to the problem. Includes presentation of data on the shape and size of inhomogeneities, and description of recording apparatus and the triangulation method used. The following parameters were determined: the velocity of the horizontal drift in the ionosphere and its direction, determined by the angle β; the average shape of the ionospheric inhomogeneities, described by the "characteristic ellipse" which is determined by the given ratio of half axes e and the direction of the large half axis (angle α); spatial dimensions of inhomogeneities; and the drift time or the drift parameter. Following the analysis of phase variation and speed of the phase change, the angles of return of the reflected waves are determined. The calculations were made on an electronic computer.

USLOVIIA NA UDARNYKH VOLNAKH V OBSHCHEI TEORII OTNOSITEL'NOSTI. V. A. Skripkin. AN SSSR Dokl., Dec. 11, 1958, pp. 799-802. In Russian. Derivation of conditions along the shock wave for the case of an ideal compressible medium in the general theory of relativity. For the centrosymmetric field, the components of the metric tensor of the four-dimensional space are shown to be continuous and their derivatives discontinuous when passing through the shock wave. The conditions for first and second arbitrary components of the metric tensor are indicated for the general case. The equations describing the motion of the ideal liquid are derived, Cauchy's problem is introduced and analyzed, and the random gravity field is determined.

POWER PLANTS

EINFLUSS DER FLUGGESCHWINDIGKEIT AUF DIE WIRTSCHAFTLICHKEIT VON STRAHLTRIEBWERKEN UND RAKETEN. G. Fellner. DVL Bericht No. 58, Dec., 1958. 59 pp. 17 refs. Westdeutscher Verlag, Köln & Opladen. In German. Study of the effect of flight speed on the economy of jet and rocket power plants. The efficiency and the specific fuel consumption of the rocket are determined in terms of real values, and simple practical formulas are derived. The transporting and accelerating of the fuel in relation to external flight speed is also considered.

ROCKET PROPULSION SYSTEMS FOR INTERPLANETARY FLIGHT (The 1959 Minta Martin Lecture). G. P. Sutton. IAS, SMF Fund Paper No. FF-21, 1959. 87 pp. 41 refs. Members, $1.00; nonmembers, $2.00. Comparison of various propulsion systems on the basis of performance criteria, environmental characteristics, vehicle requirements, reliability, current status, growth potential, and efficiency. Liquid and solid propellant rockets, propulsion systems using nuclear energy sources, arc heating rockets, magneto-plasma devices, ion rocket propulsion, solar heating rockets, and solar sails are briefly described and their current status reviewed. Engine performance requirements for different interplanetary missions are established. Predictions on various propulsion system capabilities and an analysis of multiple rocket engine reliability are included. It is concluded that electrical rockets are superior for long-time interplanetary flight, and that chemical rockets are satisfactory for most of the immediate applications in "near" space.

Rocket

EXPERIMENTAL VERIFICATION OF NOZZLE ADMITTANCE THEORY IN A SIMULATED ROCKET CHAMBER. Sotirios Lambiris. Princeton U., Squid TR PR-74-R [AD 147309], Nov., 1957. 81 pp. (Microtext.) Investigation of the boundary condition represented by the supercritical exhaust nozzle of a simulated combustion chamber in the presence of pressure oscillations, made in terms of the theoretical analyses by Tsien and Crocco. This boundary condition, expressed in terms of the nozzle admittance ratio, is used to provide a solution to the nonsteady combustion chamber equation. The theoretical dynamic pressure-amplitude response of a simulated rocket chamber using air was calculated as a function of nondimensional frequency in terms of several experimental configurations, using as one of the boundary conditions the theoretical values for nozzle admittance. The actual pressure-amplitude response was then determined experimentally, using a variable-frequency siren-type flow modulator to provide a near-sinusoidal pressure disturbance at one of several axial locations. Four different subsonic choked nozzle designs (sharp orifice, beveled orifice, linear velocity gradient, and conical) were examined at chamber Mach Numbers from 0 to 0.2 and at constant pressure. Excellent agreement was observed between the predicted and measured response characteristics, providing an indirect but satisfactory verification of the nozzle admittance theory.

ROTATING WING AIRCRAFT, HELICOPTERS

DIE EINFLÜSSE VON KOMPRESSIBILITÄT, TRAPEZFÖRMIGER ABWINDVERTEILUNG UND DES BLATTSPITZENVERLUSTFAKTORS AUF SCHLAGKOEFFIZIENTEN UND SCHUB EINES HUBSCHRAUBERROTORS. G. Brüning. DFL Inst. Flugmech. Bericht No. 101, July 24, 1958. 153 pp. 11 refs. In German. Study of the effect of compressibility, trapezoidal downwash distribution, and rotor-tip loss factors on the flutter coefficients and thrust of a helicopter rotor. Results show that, although the inclusion of these factors clarifies the aerodynamic conditions, the simpler formulas are satisfactory in most cases; and that tabulated functions can often be used instead of extensive mathematical processes.

THE OSCILLATIONS OF A MASS-SPRING SYSTEM WITH MULTI-STEP FRICTION DAMPING. J. P. Jones. Helicopter Assn. Gt. Brit. J., Feb., 1959, pp. 57-69. 10 refs. Analysis of the free and forced oscillations of a single degree of freedom system damped by a multistep friction damper. It is shown that in free oscillation the decay is similar to that obtained with viscous damping, but in this case the frequency increases as the friction increases. In forced oscillation the exact solution is little different from that obtained using an equivalent viscous damper if the ratio (natural frequency/forcing frequency) is less than 1.37. For higher values the mass will remain at rest during some part of the cycle if the friction is large enough; when the above ratio is 3, 5, 7, etc., "stops" occur, however small the friction. On the basis of these results a criterion is suggested for the use of the equivalent viscous damper in ground resonance calculations.

SPACE TRAVEL

RADAR OBSERVATIONS OF THE SECOND RUSSIAN EARTH SATELLITE (SPUTNIK II 1957 β). J. G. Davies, J. V. Evans, S. Evans, J. S. Greenhow, J. E. Hall, E. L. Neufeld, and J. H. Thomson. Royal Soc. (London) Proc., Ser. A, Mar. 24, 1959, pp. 367-376. Discussion of the contacts made using the Jodrell Bank radio telescope at frequencies of 36 and 100 mc./sec. The fading characteristics of the echoes and the factors influencing the probability of obtaining a radio echo from a satellite whose orbit is known approximately are discussed. It is suggested that fading arises from (a) Faraday rotation of the plane of the waves, (b) ionospheric scintillation, and (c) rotation of the satellite. This latter effect seems to have been responsible for most of the observed fading, and it appears that the satellite was rotating about an axis which was nearly perpendicular to its major axis.

STRUCTURES

Cylinders & Shells

AN IMPROVEMENT ON DONNELL'S APPROXIMATION FOR THIN-WALLED CIRCULAR CYLINDERS. L. S. D. Morley. Quart. J. Mech. & Appl. Math., Feb., 1959, pp. 89-99. Replacement of Donnell's equation for circular cylinders by an equation retaining the essential simplicity of the original, but whose accuracy does not decrease as the wavelength of circumferential distortion increases. Flügge's equations for the thin-walled circular cylinder are used as the standard for comparison of the approximate equations. Donnell's approximation and the improved approximation are analyzed. Eigenfunction solutions with trigonometric expressions along a generator and in the circumferential direction are presented along with the solution of the inhomogeneous equation.

COMPRESSION TESTS ON CIRCULAR CYLINDERS STIFFENED LONGITUDINALLY BY CLOSELY SPACED Z-SECTION STRINGERS. J. P. Peterson and M. B. Dow. US, NASA Memo. 2-12-59L, Mar., 1959. 22 pp. Comparison of test results from six cylinders with available theoretical results for the buckling of orthotropic cylinders. It is found that the buckling load of the cylinders can be predicted by small-deflection orthotropic-shell-buckling theories with errors of approximately 15% as compared with those predicted for unstiffened cylinders. Modification of the theories with empirical correction factors deduced from supplementary panel tests and from supplementary unstiffened-cylinder tests reduced the errors of prediction to very nominal values.

USTOICHIVOST' TSILINDRICHESKIKH OBOLOCHEK S TOCHKI ZRENIIA MATEMATICHESKOI TEORII UPRUGOSTI. K. F. Voitsekhovskaia.

AN SSSR Dokl., Dec. 1, 1958, pp. 623-626. In Russian. Study covering the stability of cylindrical shells using the equations of the mathematical theory of elasticity, neglecting the components of rotation, but taking into account the surface deformation of the body. The hollow cylinder, whose outer and inner radii are r_1 and r_2, respectively, is subjected to axial compression through a force p, relative to the surface unit. The case of the axisymmetric form of stability loss is also considered, in which the problem is reduced to the solution of a biharmonic equation.

Fatigue

THEORETICAL DETERMINATION OF LIFETIME OF COMPRESSED PLATES AT ELEVATED TEMPERATURES. George Herrmann and Hu-Nan Chu. US, NASA Memo. 2-24-59W, Mar., 1959. 21 pp. 13 refs. Presentation of a method using linearized equations throughout with the assumption that the plate material is a standard linear solid. The critical time (lifetime) is determined by reducing the time-dependent behavior to the time-independent response of purely elastic buckling. Theoretically predicted lifetimes of 2024-T3 aluminum-alloy plates at 450°F. are compared with experimental values obtained in previous work.

Plates

THE VIBRATION OF A RECTANGULAR PLATE WITH EDGES ELASTICALLY RESTRAINED AGAINST ROTATION. T. E. Carmichael. Quart. J. Mech. & Appl. Math., Feb., 1959, pp. 29-42. 11 refs. Analysis of the vibration problem by means of the Rayleigh-Ritz method. Plate deflections are represented by a set of functions which define the normal modes of vibration of a beam whose ends are elastically restrained against rotation. Values of various integrals of these functions and their derivatives are established. Frequencies are obtained from a set of linear simultaneous equations which may be solved by a simple iterative process. An approximate frequency equation, sufficiently accurate for practical purposes, and numerical tables to be used with this equation are presented.

SOME VALUES OF THE REDUCTION FACTOR FOR PLASTIC BUCKLING OF PLATES IN SHEAR. B. Emslie. Coll. of Aeronautics, Cranfield, Note No. 90, Jan., 1959. 12 pp. Calculation of the plasticity reduction factor η using the incremental plasticity theory. Comparison of theoretical and experimental values for aluminum alloy show the incremental theory to be too high. The experimental values are more in agreement with the theoretical values of η when based on the total strain theory.

SOME MIXED BOUNDARY-VALUE PROBLEMS OF AEOLOTROPIC THIN PLATE THEORY. G. M. L. Gladwell. Quart. J. Mech. & Appl. Math., Feb., 1959, pp. 72-81. Application of the theory of sectionally holomorphic functions to mixed boundary-value problems. The mixed boundary conditions are derived from plates having boundaries which are partly clamped, and partly free or subjected to specified bending moment and shear. Each problem is reduced to the solution of a series of equations relating the boundary values of sectionally holomorphic functions on opposite sides of one or more arcs. Details of the solution are given for the problem of a plate in the form of the upper half-plane, subjected to constant bending moment and shear on a segment of the real axis, and clamped along the remainder.

ÜBER DAS VERHALTEN VON SCHLANKEN STÄBEN UND DÜNNEN PLATTEN KONSTANTEN QUERSCHNITTS IM ELASTISCHEN BEREICH BEI ZEITLICH VERÄNDERLICHER LÄNGSBELASTUNG. G. Kotowski. DVL Bericht No. 68, Nov., 1958. 62 pp. 22 refs. Westdeutscher Verlag, Köln & Opladen. In German. Study of the behavior of slender bars and thin plates of constant cross section under time-varying axial loads. The survey of previous investigations covers experimental results and various methods used. The effect of the inert mass of the structural elements - i.e., the inertia effects produced during deformation, is emphasized. Included are such problems as: derivation of a system of partial differential equations for longitudinal and transverse loads, as well as establishment of initial and boundary conditions; introduction of simplifying assumptions; solution of differential equations for the lateral motion in the case of a flexible arrangement of the bar; solution of differential equations for other mounting conditions relative to bending; and extension of the theory to the case of thin plates.

Thermal Stress

VLIIANIE NERAVNOMERNOGO NAGREVA V USLOVIIAKH POLZUCHESTI NA IZMENENIE NAPRIAZHENNOGO SOSTOIANIIA. B. F. Shorr. AN SSSR Dokl., Dec. 11, 1958, pp. 809-812. In Russian. Study of the effect of nonuniform heating on stress variations under conditions of creep. The case of parabolic temperature distribution along the width of a bar is covered, and the importance of taking into account the time dependent stress variation is emphasized.

THERMODYNAMICS

Combustion

THEORY OF FLAME PROPAGATION. Y. B. Zeldovich and G. I. Barenblatt. Comb. & Flame, Mar., 1959, pp. 61-74. 16 refs. Review of previous work on steady state propagation of flat flames and comparison of various mathematical techniques. In the numerical evaluation of the velocity of uniform propagation of flames, the effects of varying parameters, heat loss, and chain reactions are considered, leading to an analysis of stability of propagation. Limits of validity are given.

METHODES ALGEBRIQUES DE CALCUL DE LA COMPOSITION A L'EQUILIBRE DES PRODUITS DE REACTIONS HAUTEMENT ENERGETIQUES. E. Le Grivès and S. Barrère. La Recher-

che Aéronautique, Jan.-Feb., 1959, pp. 31-37. In French. Evaluation of methods for the calculation of equilibrium composition of chemical reactions in rocket propellants. The applicability of each method is illustrated by specific examples. The system of equations representing the equilibrium conservation of various constituents is considered and a general method of solution is developed, using successive approximations by linearizing the system of basic equations. A more direct method, which does not involve an initially assigned value for the pressure, is also indicated. The third method introduces the concentrations of the main components into a more reduced intermediary system and uses iterations to determine the corrections necessary for the total of constituents.

METHODE OPTIQUE DE MESURE INSTANTANEE DE LA TEMPERATURE DES FLAMMES. A. Moutet, C. Veret, and L. Nadaud. La Recherche Aéronautique, Jan.-Feb., 1959, pp. 10-19. 15 refs. In French. Development of an optical method for measuring flame temperatures, based on the Kurlbaum and Fery procedure. The results, obtained by means of an electronic computer, are in good agreement with theoretical values. Two approaches are used in the investigation for isolating the radiations: (a) that involving a classical monochromator and (b) that using an interferential filter. The study includes the combustion of solid and liquid propellants, as well as the instability of combustion in jet and rocket power plants. Two types of information are supplied by this method: (a) measurement of peak temperatures for each cycle, obtained by the introduction of a large time constant into the electronic conversion of the light signal; and (b) the instantaneous measurement used to study each fluctuation.

COMPARISON BETWEEN HOT-GAS IGNITION AND LIMIT FLAME TEMPERATURES. M. Vanpée and H. G. Wolfhard. US, Bur. Mines, Pittsburgh, Squid TR BUM-26-P [AD 203451], Sept., 1958. 13 pp. (Microtext.) Measurement of ignition temperatures for (a) 100 cu. cm./sec. hot air going into pure fuel, and (b) 100 cu. cm./sec. hot nitrogen going into a fuel-air mixture. The effects of ethane-air and CO-air mixtures as additives on hot-gas ignition temperature are studied. The data indicate a relationship between hot-gas ignition temperatures and limit temperatures of stoichiometric flames, showing that the same reactions are responsible for flame propagation under limiting conditions and hot-gas ignition under critical conditions.

Heat Transfer

TEMPERATURE FLUCTUATIONS OVER A HEATED HORIZONTAL SURFACE. Appendix - THE RELATION BETWEEN RATE OF CHANGE OF TEMPERATURE AND TEMPERATURE GRADIENT IN TURBULENT FLOW. A. A. Townsend. J. Fluid Mech., Feb., 1959, pp. 209-241. 21 refs. Experimental investigation to measure the distribution of mean temperature, the mean squares of the temperature fluctuation, the temperature gradient and the rate-of-change of temperature, and the statistical distributions of these quantities. It is observed that the quantities measured all show periods of activity, characterized by large fluctuations, alternating with periods of quiescence with comparatively small ones. It is concluded that the quiescent fluctuations are typical of the turbulent convection far from the surface while the active fluctuations are the manifestation of the convective process arising near the rigid boundary. The Malkus theory of turbulence, which emphasizes dependence on the conduction layer, is in qualitative agreement with this inferred mechanism of the convection and is in quantitative agreement with the observed distributions of mean temperature.

THE MECHANISM AND APPLICATION OF EFFUSION COOLING. P. Grootenhuis. RAeS J., Feb., 1959, pp. 73-89. 65 refs. Study of the effusion cooling mechanism considering the internal heat transfer between the porous material and the coolant in which the heat transfer coefficient is obtained experimentally. An approximate analysis for the heat insulating effect based on a heat balance method is derived and applied to experiments. The analysis is found to apply reasonably well with experimental results. The manufacture of porous materials is discussed and a representative list of commercially available materials is included. The application of effusion and sweat cooling to the blading and combustion chamber linings for gas turbines, rocket motors, and the outside skin of flying vehicles is considered.

VTOL & STOL

SOME AERODYNAMIC CHARACTERISTICS OF WING-MOUNTED LIFTING FANS FOR VTOL APPLICATIONS. R. L. Wardlaw and N. V. McEachern. Can. Aero. J., Mar., 1959, pp. 99-109. Description of wind-tunnel force measurements carried out on a wing-fan combination; the high-solidity fan was embedded in a two-dimensional symmetrical wing, with the fan axis normal to the wing chord plane. The test results are discussed and compared with a simple momentum theory, with a view to their applicability in VTOL project studies. A method for applying the results to performance analyses is considered.

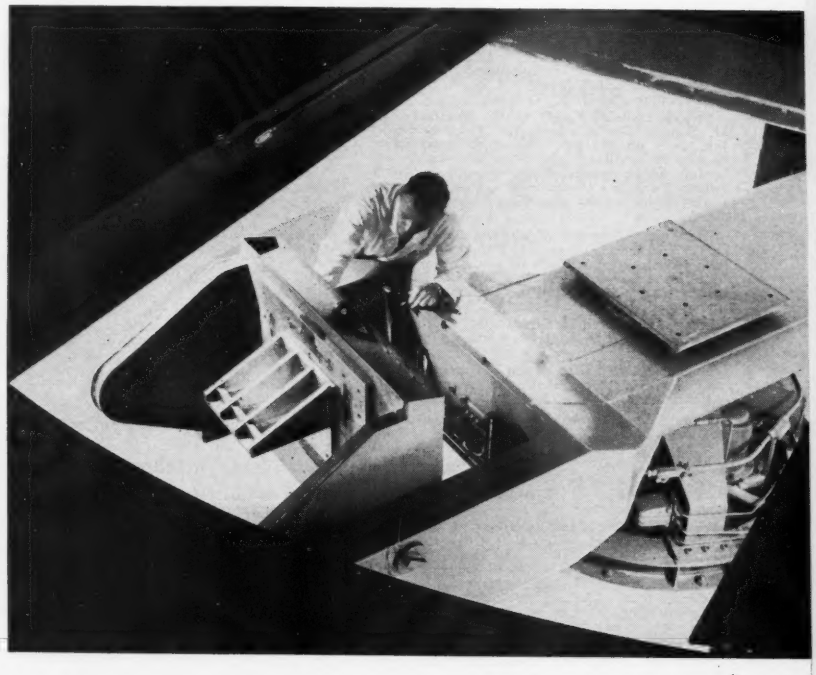
WATER-BASED AIRCRAFT

HYDRODYNAMIC IMPACT-LOAD ALLEVIATION WITH A PENETRATING HYDRO-SKI. P. M. Edge, Jr. US, NASA Memo. 1-9-59L, Feb., 1959. 31 pp. 16 refs. Presentation of a series of impact tests made at fixed trim angles of 8°, 16°, and 30° in smooth water and at a fixed trim angle of 8° in rough water. Maximum impact loads and maximum drafts of the model with the penetrating hydro-ski are compared with those obtained on the model without the penetrating hydro-ski. Maximum load reductions of 30% and 70% in smooth water and of 50% to 80% in rough water are indicated. Cavity and flow generation by the penetrating hydro-ski are discussed, and it is indicated that the penetrating hydro-ski moved smoothly through the water and generated deep cavities.

(left) Navy Polaris AX-1 flight test vehicle at beginning of launch. Lockheed's Polaris fleet ballistic missile is more than a year ahead of original schedule.

(below left) One of the Santa Cruz test stands with dynamic thrust mount to simulate flight environment. Vibration oscillator functions during static firings.

(below right) Large centrifuge for environmental testing has unique shaker attachment to provide vibration simultaneously with high G-loadings.



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On Vitali's Theorem for Complex Spaces with Singularities. R. C. Gunning. *J. Math. & Mech.*, Jan., 1959, pp. 133–141.

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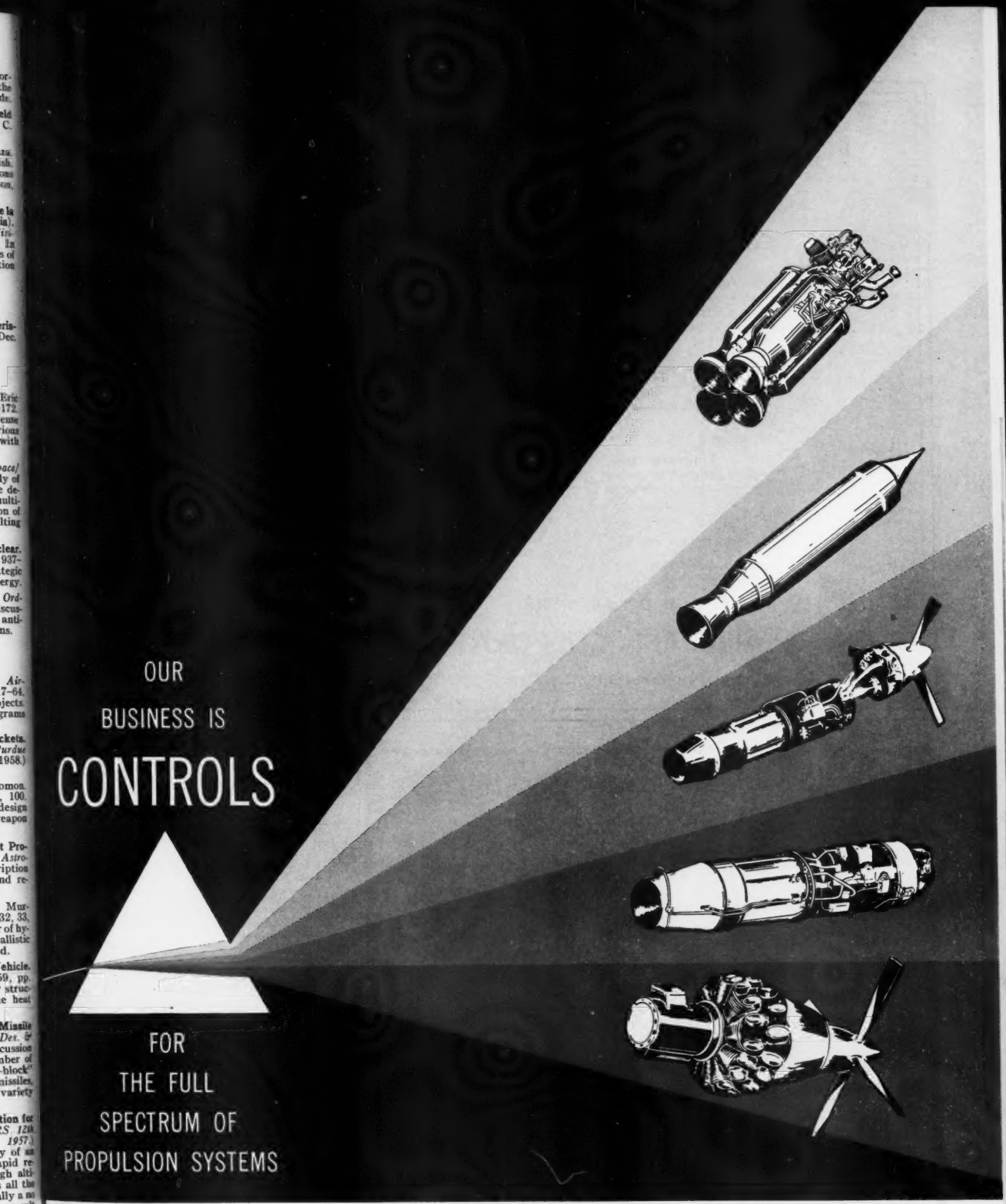

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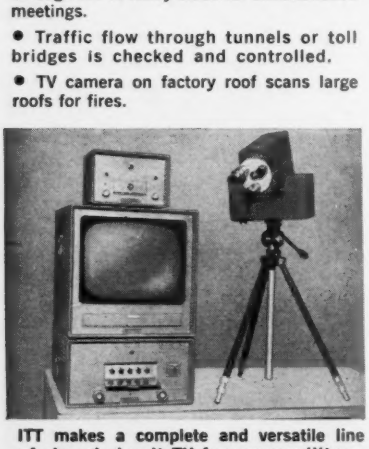

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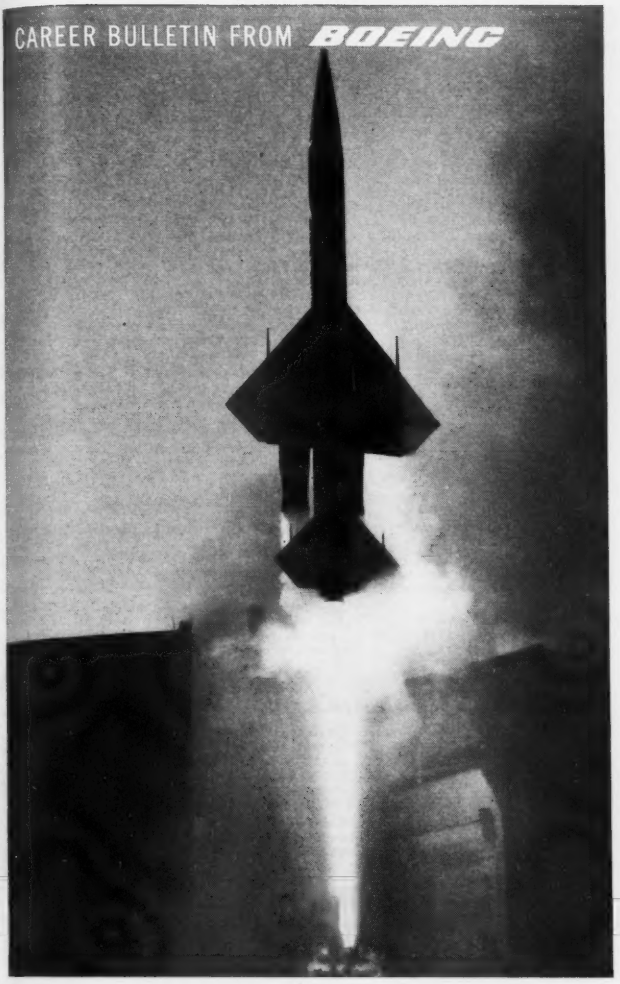

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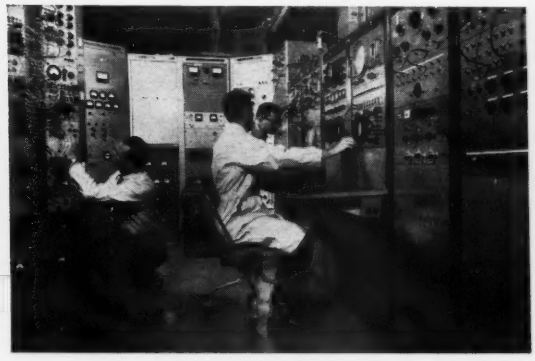

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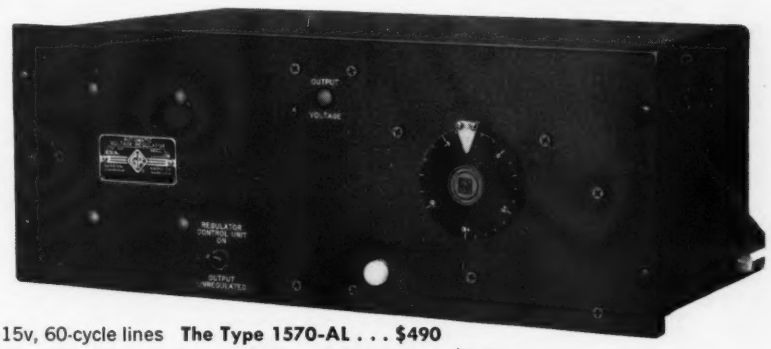

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Powloki Wzmocnione Belkami. Augustyn Borcz. *Rozprawy Inżynierskie*, No. 3, 1958, pp. 407–430. In Polish, with summaries in English and Russian. Presentation of a method for computing shells stiffened with beams. A numerical example illustrating the method is given, and results are represented graphically.

Studia nad Kształtem Błonowych Powłok Obrotowych Stanie Plastycznym. Zdzisław Marciniak. *Rozprawy Inżynierskie*, No. 3, 1958, pp. 483–494. In Polish, with summaries in English and Russian. Establishment of a relation enabling the graphical determination of the form of the shell corresponding to the given boundary conditions. Examples of shell forms obtained for various loads are given, and technological processes are indicated for which the sheet takes a form approaching that determined theoretically.

Elasticity & Plasticity

The Characteristic Method of Solution for the Problem of Plane Plastic Strain. J. Halling. *The Engr.*, Feb. 13, 1959, pp. 250–254. 10 refs. Solution of the hyperbolic linear partial differential equation of plane plastic strain by a series of characteristic curves which allow the determination of the stress and velocity conditions at all points in the deforming zone.

Obratnaia Zadacha Prikladnoi Teorii Plastichnosti dlia Staticheski Neopredelimykh Balok. R. A. Mezhlumian. *AN SSSR Otd. Tekh. Nauk Izv.*, Dec., 1958, pp. 144–147. In Russian. Derivation of a solution for the inverse problem of statically indeterminate beams and establishment of certain singularities observed in the solution of inverse problems.

Dinamicheskii Raschet Priamougol'noi Plity, Lezhashchei na Odnosloinom Uprugom Osnovanii. A. N. Elpat'evskii. *AN SSSR Otd. Tekh. Nauk Izv.*, Dec., 1958, pp. 136–140. In Russian. Dynamic calculation of rectangular plates on elastic supports.

Tłumienie Falami Naprężeń w Belkach Sprężystych. Jozef Więckowski. *Rozprawy Inżynierskie*, No. 3, 1958, pp. 431–452. 17 refs. In Polish, with summaries in English and Russian. Analysis of stress damping in elastic beams by means of waves. Results are illustrated by simple examples.

Dynamiczna Teoria Plastyczności Jako Pomost Między Teorią Sprężystości a Teorią Plastyczności. Jan Madejski. *Rozprawy Inżynierskie*, No. 3, 1958, pp. 467–481. In Polish, with summaries in English and Russian. Study showing the possibility of analyzing the state of stress and strain by means of the dynamic theory of plasticity, if the state changes from elastic to plastic.

Propagation of Plastic Waves in Solids. J. F. Bell. *J. Appl. Phys.*, Feb., 1959, pp. 196–201. Experimental study of large amplitude plastic waves in annealed aluminum. It is shown that, by using the diffraction grating method, strain-time, surface angle-time, and Poisson's ratio for the case of constant velocity impact in cylindrical rods can be determined accurately.

Ob Odnom Klasse Reshenii Obshchikh Uravnenii Teorii Ideal'noi Plastichnosti. D. D. Ivlev. *AN SSSR Otd. Tekh. Nauk Izv.*, Nov., 1958, pp. 106–109. In Russian. Evaluation of a class of solutions for the general equations in the theory of ideal plasticity for the case of Mises conditions.

L'Instabilità Flesso-Torsionale in Regime Elasto-Plastico. Elio Giangreco, Cesare Foti, and Alfredo Sollazzo. *Tec. Ital.*, Dec., 1958, pp. 513–528. 12 refs. In Italian. Study of the flexural torsional instability, including derivation of a law for the variation of critical load as function of the elastic and geometric parameters. Experimental results agree with theoretical predictions.

K Ploskoi Zadache Teorii Uprugosti pri Proizvol'nykh Ob'emnykh Silakh. P. P. Teodoresku. *Rev. Méc. Appl.*, No. 1, 1958, pp. 101–108. In Russian. (Also in *Stud. Cerc. Mec. Aplic.*, No. 2, 1958, pp. 391–410.) Study of the plane problem in the theory of elasticity for the case of arbitrary forces. The derived results can be used for the calculation of beams subjected to concentrated internal loads.

Fatigue

Presentation of Fatigue Test Results. J. Strebelle. *Brit. Welding J.*, Feb., 1959, pp. 65–71. Study showing the simplicity of using statistical methods in the presentation of fatigue test results. Three ranges of stress cycles are considered, and an example of graphical representation on a Wöhler diagram is given.

Plates

The Bending of Transversally Non-Homogeneous, Moderately Thick Plates. M. Sokolowski. (*Arch. Mech. Stosowanej*, No. 3, 1958.) *Acad.*

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Pol. Sci. Bul., Tech. Sci. Ser., No. 4, 1958, pp 181–186.

Primenenie Metoda Nachal'nykh Funktsii k Raschetu Tolstykh Plit. E. I. Silkin and N. A. Solov'eva. *AN SSSR Otd. Tekh. Nauk Izv.*, Dec., 1958, pp. 141–143. In Russian. Application of the method of initial functions to the calculation of thick plates.

Kolebaniia Plit s Uchetom Inertsii Vrashcheniia i Sdviga. M. V. Dubinkin. *AN SSSR Otd. Tekh. Nauk Izv.*, Dec., 1958, pp. 131–135. In Russian. Calculation of the transversal vibrations of plates, taking into account rotational inertia and displacement.

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Ob Izgibe Priamougol'noi Uprugoi Plastinki, Dvizhushcheisia v Gaze s Postoiannoi Sverkhzvukovoi Skorost'iu. B. F. Vlasov. *AN SSSR Otd. Tekh. Nauk Izv.*, Dec., 1958, pp. 124–127. In Russian. Study of the state of stress and deformation for the case of a thin elastic rectangular plate moving at constant supersonic speed in a gaseous medium.

Izgib Ellipticheskoi Anizotropnoi Plastinki, Zadelannoi po Kraiu. L. D. Korbukova. *AN SSSR Otd. Tekh. Nauk Izv.*, Dec., 1958, pp. 78–84. In Russian. Study of the bending of an elliptic anisotropic plate sealed along the edge L and subjected to stresses applied at its center.

Elastic-Plastic Bending of Non-Homogeneous Orthotropic Plates. W. Olszak and J. Murzewski. (*Arch. Mech. Stosowanej*, Nos. 4; 5, 1957.) *Acad. Pol. Sci. Bul., Tech. Sci. Ser.*, No. 4, 1958, pp. 211–218. 12 refs.

Płyty Wzmocnione Belkami. Augustyn Borcz. *Rozprawy Inżynierskie*, No. 3, 1958, pp. 349–406. 27 refs. In Polish, with summaries in English and Russian. Establishment of the boundary conditions for a plate stiffened with edge beams. The process is based on the assumptions that: (a) the edge beam is deformed in the same way as the plate at the contact line, and (b) the conditions of equilibrium of the beam and the plate are preserved.

The General Case of Axisymmetric Bending of Elastic-Plastic Plates. W. Olszak and J. Murzewski. *Acad. Pol. Sci. Bul., Tech. Sci. Ser.*, No. 4, 1958, pp. 219–228. Analysis of axially symmetric bending of a circular or ring-shaped plate when the plate exhibits orthotropy.

Stress Distribution in a Rectangular Plate Subject to Forces Acting in its Plane. Minoru Hamada. *JSME Bul.*, Nov., 1958, pp. 367–374. Application of the strain energy method to the problem of stress distribution, and investigation of its accuracy through numerical calculations.

On the Transverse Flexure of a Semi-Infinite Thin Plate with a Semi-Circular Notch. Osamu Tamate and Shunsuke Shioya. *JSME Bul.*, Nov., 1958, pp. 357–361. 11 refs. Determination of the stress resultants in a semi-infinite plate under plain bending by means of the Poisson-Kirchhoff theory of thin plates and the complex variable method. Numerical results are presented in graphical form.

Sobre el Campo de Tensión Diagonal. P. Cicala and G. L. Ventura. *La Plata U. Nac. Fac. Cienc. Fisicomat. Dept. Aero. Pub. 61*, 1958. 20 pp. 16 refs. In Spanish. Study of the effect of a particular initial deformation in a stiffened strip loaded in shear. Results are presented and evaluated.

O Problemă de Tip Mixt din Încovoierea Plăcilor Elastice. Cristian Stănescu. *Stud. Cerc. Mec. Aplic.*, No. 2, 1958, pp. 411–421. In Rumanian, with summaries in Russian and French. Study of the flexural problem of a thin, isotropic, elastic plate with load applied to the mean surface.

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Make Strain Visible with PhotoStress Analysis. Felix Zandman. *Prod. Eng.*, Mar. 2, 1959, pp. 43–46. Presentation of the photostress technique for observing and reading strains in structures and parts under load. Current practical applications are described.

A Photoelastic Study of Strain-Energy Storage Near a Crack. Y. F. Cheng, B. D. Mills, Jr., and E. E. Day. *Trend in Eng.*, Jan., 1959, pp. 15–18. Application of a photoelastic fringe multiplication technique to evaluate some analytically determined values of strain-energy storage near a crack in sheet material under tension.

Thermal Stress

Thermal Stresses in Design. VII—Exact and Approximate Solutions. S. S. Manson. *Mach. Des.*, Feb. 5, 1959, pp. 114–121. 19 refs. Discussion of two types of exact solutions for thermal stresses: explicit solutions in closed form and solutions in terms of infinite series. Final equations are presented for thermal stress problems which relate to certain classical body shapes.

Thermal Stresses in Design. IX—Elastic-Stress Solutions. S. S. Manson. *Mach. Des.*, Mar. 5, 1959, pp. 125–130. 16 refs. Application of the reciprocal theorem and the finite difference method to stress problems.

Thermal Stresses in Design. VI—Elastic Stress Analysis. S. S. Manson. *Mach. Des.*, Jan. 22, 1959, pp. 126–131. 12 refs. Presentation of an outline of methods effective for determining thermal stresses in the elastic range.

O Plasticheskikh Deformatsiiakh Tolstostennoi Truby pod Deistviem Teplovykh Impul'sov i Davleniia. A. A. Il'iushin and P. M. Ogibalov. *AN SSSR Otd. Tekh. Nauk Izv.*, Dec., 1958, pp. 85–89. In Russian. Study of the plastic deformation of a thick-walled duct under the effect of heat impulses and pressure.

Thermal Stresses in Design. VIII—Elastic Stresses by Energy Methods. S. S. Manson. *Mach. Des.*, Feb. 19, 1959, pp. 156–160. 15 refs. Presentation of four methods for computing thermals stresses: (a) complementary energy, (b) single product method, (c) self-equilibrating polynomials, and (d) station functions.

Tubes

A Creep Instability of Thin-Walled Tubes Under Internal Pressure. Iain Finnie. *J. Aero/Space Sci.*, Apr., 1959, pp. 248, 249. Analysis showing that the deformation of a tube due to creep leads to a maximum tube life which can be predicted from tensile creep data.

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Concise, Systematic Jacobian Thermodynamics for High-Temperature Real Gases. R. J. Arave. *J. Aero/Space Sci.*, Apr., 1959, pp. 250–253. Presentation of tables for common thermodynamic quantities generalized in order to account for real-gas effects. The tables are based on a functional analysis by Shaw for obtaining any thermodynamic partial derivatives of a simple system in terms of reference partial derivatives.

Some Thermodynamic Properties of a Mapping. D. E. Christie. *Franklin Inst. J.*, Feb., 1959, pp. 119–134. Study of the relationships between mathematical and physical aspects of a basic thermodynamic situation. Topological foundations, the interplay of disciplines, and generalized specific heats and bulk moduli are considered.

Thermodynamic Properties of Gases at High Temperature. I—Chemical Equilibrium Among Molecules, Atoms, and Atomic Ions Considered as Clusters. H. W. Woolley. *J. Res.*, Dec., 1958, pp. 469–490. 35 refs.

Combustion

The Generalized Thermal Energy in Boundary Layer Type Flows with Chemical Reaction. S. F. Shen. *ZAMM*, Nov.-Dec., 1958, pp. 431–436. Analysis of previous studies of certain combustion phenomena and development of a simplified method particularly applicable to (a) combustion problems with mixing and (b) boundary layer flows over flat surfaces.

The Ignition of Gases by Electrically Heated Wires. II. L. E. Ashman and W. E. Gordon. *USAF OSR TN 58-1011 [AD 206154]*, Jan. 19, 1958. 21 pp. 17 refs. Investigation of the ignition of stoichiometric hydrogen-air and methane-air mixtures. It is concluded that the methane-air reaction is at least partially thermal in character, while the hydrogen-air reaction is essentially due to a chain-carrier mechanism.

Growth of Disturbances in a Flame-Generated Shear Region. Appendix—**Axisymmetric Disturbances in Axisymmetric Flow with Density Jumps.** P. L. Blackshear, Jr. *U.S., NACA Rep. 1360*, 1958. 46 pp. 38 refs. Supt. of Doc., Wash., $0.50. Stability analysis of the flow field arising when a flame is anchored in a duct, and experimental examination of the growth of disturbances imposed on an anchored V-flame in a duct.

Heat Transfer

A Variational Problem Relating to Cooling Fins. R. J. Duffin. *J. Math. & Mech.*, Jan., 1959, pp. 47–56. Analysis considering the problem of finding the taper which gives the maximum dissipation of heat for a given weight of fin. Solution of Euler equations shows that the Schmidt criterion holds true—i.e., the temperature is a linear function of the distance along the fin. Methods for finding the upper and lower bounds of the Sturm-Liouville equation are presented. These methods can be used to calculate the effect of departure from the optimum taper in cooling fins.

Raspredelenie Temperatury v Neogranichennom Polom Tsilindre pri Teploobmene na Granitsakh so Sredami Peremennoi i Postoiannoi Temperatury. I. N. Danilova. *AN SSSR Otd. Tekh. Nauk Izv.*, Dec., 1958, pp. 148–150. In Russian. Study covering the problem of temperature distribution in an infinite hollow cylinder for the case of heat transfer on the boundaries in contact with media of constant and variable temperature.

On the Convective Heat Transfer for Turbulent Flow of Single-Phase Fluid Through Concentric Annuli. Wang Pu-Hsuan. *Scientia Sinica*, Jan., 1959, pp. 98–109. 29 refs.

VTOL & STOL

The Hiller X-18 Tilt Wing Aircraft. J. B. Nichols. *FSF 9th Annual Internatl. Air Safety Seminar, Palo Alto, Nov. 11–15, 1957, Paper.* 9 pp. Discussion of the basic characteristics and design features of the tilt wing propelloplane. The operational and safety conditions of the X-18 research aircraft are also included.

Triebwerke für VTOL-Flugzeuge. P. G. Kappus. *Der Flieger*, Mar., 1958, pp. 87–90. In German. Survey of various power plant types for VTOL application.

And Some on STOL. II. James Hay Stevens. *Aircraft* (Canada), Jan., 1959, pp. 10–14, 62, 63. Discussion covering various devices of boundary-layer control for STOL aircraft.

Le Pilotage de l'Atar Volant. G. Ernst and J. Jardinier. *Tech. & Sci. Aéronautiques*, June, 1958, pp. 129–134. 12 refs. In French. Discussion covering the flight mechanics of the Atar Volant, including problems of stability and control.

Aerial Jeeps for the U.S. Army. Howard Levy. *The Aeroplane*, Feb. 13, 1959, pp. 196–198. Summary of papers giving requirements for aerial jeeps, studies of stability and control, and design characteristics of three vehicles being built by Chrysler, Aerophysics, and Piasecki.

K Voprosu Otkloneniia Svobodnoi Strui Potoka. N. N. Patraulia. *Rev. Méc. Appl.*, No. 1, 1958, pp. 5–15. In Russian. Study covering the problem of free-stream deflection as applied to the case of vertical take off. The method of calculation is demonstrated and some numerical results are presented.

Water-Based Aircraft

The Effect of Beam Loading on Water Impact Loads and Motions. J. S. Mixson. *U.S., NASA Memo. 1-5-59L*, Feb., 1959. 40 pp. 12 refs. Test results for narrow beam models, and analysis of these results to show trends of the high beam-loading data with time, initial flight-path angle, and dead-rise angle. An empirical equation for the prediction of maximum lift coefficient is developed.

Seaplanes Need Open-Sea Capability. D. B. Mac Diarmid. *SAE J.*, Jan., 1959, pp. 74, 75. Discussion of necessary design features and the research data needed for a new seaplane.

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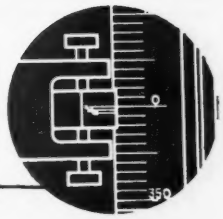

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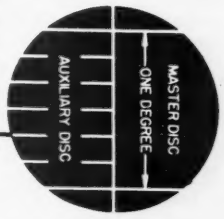

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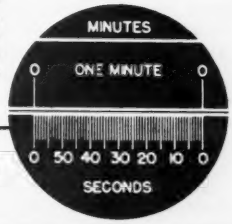

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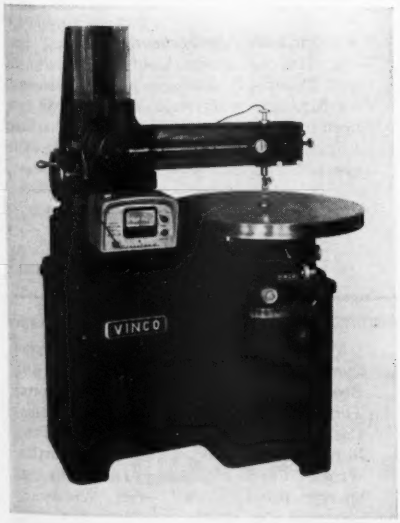

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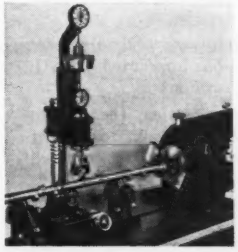

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IAS News *(Continued from page 19)*

Chief Engineer of the San Diego Division of Convair.

Robert D. Gilson (M) has been promoted to C-130 Project Engineer by Lockheed Aircraft Corp.'s Georgia Division. He was formerly Assistant Project Engineer.

P. A. Haythorne (M) has been appointed Technical Director for Superweld Corp., California. He was formerly Chief Engineer and Manager of Product Development for the Aircraft Division of Rheem Manufacturing Co.

J. A. Jaeger (M), formerly Project Engineer, has been named Manager of a new engineering unit established by Lockheed Aircraft Corp.'s Georgia Division to engineer a major fuselage section of the B-70 Valkyrie intercontinental bomber.

Frank W. Kux (M) has been assigned to the Washington, D.C., area as a company representative of Marquardt Aircraft Co. He was formerly an Applications Supervisor of the Preliminary Design Department in the Propulsion Division.

Norman V. Petersen (M), formerly with Sperry Gyroscope Co. at Sunnyvale, Calif., has been appointed Chief of the Astronautics Group, Norair Division of Northrop Corp.

John W. Pocock (AF), partner with Booz, Allen & Hamilton, has been elected Chairman of the Executive Committee of Booz, Allen Applied Research, Inc. He will be Chief Executive Officer.

D. R. Shoults (AF) has been named recipient of the "Engineer-Scientist of the Year" award by the Cincinnati Technical and Scientific Societies Council. Mr. Shoults is General Manager of the General Electric Aircraft Nuclear Propulsion Dept.

Hyman Stein (M), Project Manager on space projects, Republic Aviation Corp., has been appointed Consultant to the Aero and Space Vehicles Panel of the Air Force Scientific Advisory Board. The panel is one of ten organized to advise the Air Force Chief of Staff.

George P. Sutton (M) has been named Chief Scientist of the Defense Department's Advanced Research Projects Agency. Mr. Sutton is Hunsaker Professor of Aeronautical Engineering at M.I.T.

T. R. Thoren (M), formerly Staff Director, Engineering, Research, & Development for Thompson Products Divisions, has been named Assistant to the Vice-President and General Manager of the Ramo-Wooldridge Division.

Richard P. White (M), formerly Chief Technical Engineer, has been promoted to Assistant Chief Engineer for Product Design, San Diego Division of Convair.

IAS News — Corporate Member News

• **Avien, Inc.,** has named Norman C. Pickering as Vice-President and Technical Director. He will be responsible for planning and coordination of technical and quality growth.

• **Bendix Aviation Corp.** has acquired the property and assets of the M. C. Jones Electronics Co., Inc., Bristol, Conn., as part of its policy of diversification and expansion in electronics. Two new directors were elected—Edward K. Foster and A. P. Fontaine. Mr. Foster is Vice-President and Group Executive in charge of divisional operations at Baltimore, York, Pa., and Cincinnati; Mr. Fontaine is Engineering Vice-President of the company. Dugald Black has been promoted to Vice-President in charge of industrial relations and has been made a member of the Administration Committee.

• **Bulova Research and Development Laboratories, Inc.,** has appointed John J. Carpenter a Vice-President.

• **Chicago Aerial Industries, Inc.,** in an effort to centralize all planning for plant and equipment expansion, has created the new post of Director of Facilities Planning to which George Hoeck, now Vice-President—Manufacturing, has been named.

• **Cornell Aeronautical Laboratory, Inc.,** has named Anton Johnson Assistant Head of the Weapon Systems Design Department.

• **Del Mar Engineering Laboratories** has made Albert W. Powers Manager of Customer Service.

• **Fairchild Engine and Airplane Corp.** has elected C. Leo De Orsey, Washington attorney, to its Board of Directors.

• **General Dynamics Corp....** Stromberg Carlson Division's Electronic Control Systems facility has opened an automatic data processing center on the West Coast; its function is preparation of magnetic tapes to be used to operate numerically controlled machine tools. Henry M. Taylor has been made Manager of Military Marketing for the Electronics Division.

• **General Electric Co....** Flight Propulsion Division is the new name of the Aircraft Gas Turbine Division.

• **ITT Laboratories, Division of International Telephone & Telegraph Corp.,** has elected Robert S. Caruthers as Vice-President and Technical Director. Andre G. Clavier, who retired a short time ago as Vice-President and Technical Director, has been appointed Scientific Adviser to the President.

• **Lockheed Aircraft Corp.** has elected W. Gifford Myers as Corporate Vice-President of Sales. An Electronics and Avionics Division has been established, with Dr. Louis N. Ridenour as General Manager.

• **The Martin Co.** announced appointment of Dr. George D. Sands as Director of Scientific Requirements.

• **North American Aviation, Inc....** Autonetics Division has announced that Drs. Arnold Miller and Josef Kasper have joined the Research Staff of their Advanced Engineering Dept. E. A. Holmes, III, has been named Product Manager, Industrial Products.

• **Northrop Corp.** has announced acquisition of Page Communications Engineers, Inc., which will be operated as a wholly owned subsidiary. This marks their expansion into the new field of advanced systems for long-range radio communications. . . . Nortronics Division's plans to build a new $4,000,000 engineering, R&D, and pilot production facility have been approved.

• **Pan American World Airways, Inc.,** announced plans for jet service between the United States and South America beginning late last month. All-cargo service across the Pacific was inaugurated on April 1.

• **Radio Corp. of America, Defense Electronic Products,** has appointed John B. Coleman to the newly created position of Administrator, High Power Transmitters, to spearhead further development of RCA defense-product capabilities in this field.

• **Simmonds Aerocessories, Inc.,** has opened a San Diego, Calif., branch office, and Thomas S. Simpson has been named its Manager. Harrison F. Edwards has been promoted to Chief Engineer, Product Engineering, of the Manufacturing Division in Vergennes, Vt.

IAS News — IAS Sections

Detroit Section

Symposium and Display Highlight Meeting

Displays of ten manufacturers of gas-turbine engines, components, and accessories, highlighted by an exploded model of the original small gas-turbine engine designed and built by the Chrysler Corp., were on view at the Third Annual Small Gas-Turbine Symposium and Display. Other exhibitors were AC Spark Plug Div., GMC; Aeroquip Corp.; The Champion Spark Plug Co.; Cleveland Graphite and Bronze Co., Div. of the Clevite Corp.; The Haynes Stellite Co., Div. of Union Carbide Corp.; Pesco Products Div., Borg-Warner Corp.; Utica Div., Curtiss-Wright Corp.; Vickers, Inc., Div. of Sperry Rand Corp.; and Woodward Governor Co.

The technical papers included a paper entitled **"Spark Igniters for Gas-Turbine Engines"** by **L. R. Lentz,** Assistant Director of Engineering, Champion Spark

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For Names — Current Addresses — Complete Product Descriptions of all principal manufacturers of Missile, Rocket, Air and Spacecraft Components and Materials.

▶ Specific product data of these leading companies are filed in the 1959 AERO/SPACE ENGINEERING CATALOG.

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Aeroquip Corp.
Aero Supply Mfg. Co., Inc.
Aircraft Radio Corp.
AiResearch Mfg. Divs., The Garrett Corp.
Allied Research & Engineering Div., Allied Record Mfg. Co.
The American Brass Co.
American Felt Co.
Amphenol-Borg Electronics Corp.
Behlman Engineering Co.
Bendix Products Div., Bendix Aviation Corp.
Buffalo Hydraulics Div., Houdaille Industries, Inc.
Chain Belt Co., Shafer Bearing Div.
Chandler-Evans Corp.
Cherry Rivet Div., Townsend Co.
Chicago Aerial Industries
Cleveland Pneumatic Tool Co., a Div. of Cleveland Pneumatic Industries, Inc.
Consolidated Controls Corp.
Delavan Manufacturing Co.
Douglas Aircraft Co., Inc.
Eastern Industries, Inc.
Thomas A. Edison Industries, Instrument Div., McGraw Edison Co.
Elastic Stop Nut Corp. of America
Flexonics Corp.
Garrett Corp., The, AiResearch Mfg. Divs.
General Electric Co., X-Ray Dept.
General Logistics Div., Aeroquip Corp.
Hoover Electric Co.
Houdaille Industries, Inc., Buffalo Hydraulics Div.
Janitrol Aircraft Div., Surface Combustion Corp.
Johns-Manville
Joy Manufacturing Co.
Kearfott Co., Inc.
Kelsey-Hayes Co.
Kollsman Instrument Corp.
Lavelle Aircraft Corp.
Link-Belt Co.
Marman Div., Aeroquip Corp.
McGraw Edison Co., Thomas A. Edison Industries, Instrument Div.
Meletron Corp.
Microbeads, Inc.
The Narda Ultrasonics Corp.
The New York Air Brake Co., Watertown Div.
Pioneer Parachute Co., Inc.
Resistoflex Corp.
M. H. Rhodes, Inc.
Rohr Aircraft Corp.
Scott Aviation Corp.
Shafer Bearing Div., Chain Belt Co.
Sierra Engineering Co.
Southwest Products Co.
Standard Pressed Steel Co.
Standard Wire & Cable Co.
F. W. Stewart Corp.
Surface Combustion Corp. Janitrol Aircraft Div.
Swedlow Inc.
Telecomputing Corp., Whittaker Controls Div.
Townsend Co., Cherry Rivet Div.
United States Steel Corp.
Universal Match Corp.
Watertown Div., The New York Air Brake Co.
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Plug Co.; and a paper entitled **"The General Electric T58: How the Design of a Successful Small Gas-Turbine Engine Is Accomplished"** by **Leonard J. Nuttall,** T58 Applications Engineer, General Electric Co.

Mr. Lentz presented a brief history of the development of igniters and ignition systems for gas-turbine engines; a description of the present state of igniter development, including some design principles; a discussion of some service problems; and predictions for igniter developments for future applications and requirements.

Mr. Nuttall gave a dynamic paper on a very significant engine development, the General Electric T58. This power plant is the only American-designed shaft power gas-turbine engine ever licensed for manufacture in England. Mr. Nuttall described design philosophy and features of the T58, together with an account of some of the significant operating experience to date, including flight and environmental testing, engine development, and air and land engine applications.

WILLIAM M. SPREITZER, *Secretary*

Hagerstown Section

FAA's Hoekstra Discusses Transport Development

The main objective in transport development during the next 10 years will be the refinement of present-day turbine transports, according to **Harold Hoekstra** in his talk on **"Transport Developments"** at a February meeting. Mr. Hoekstra, who is Chief Project Officer—Transports, Federal Aviation Agency, also said that the possibility of production of a supersonic (Mach 3) transport would be realized in about 1970.

Regarding certificate applications before the FAA, he said that at the present time there were no piston engine type certifications on file. As of February 1, 1959, however, there were twelve United States and twelve foreign turbine engine types on file. Also, as of that date, there were three U.S. and four foreign turbine-powered aircraft certificated for airline use. He added that first certification standards on turbine-powered aircraft were issued by the FAA (then the CAA) back in 1946. Mr. Hoekstra concluded his talk with a film on fluorescent touch-down lighting tests at Washington National Airport.

(For the complete text of Mr. Hoekstra's remarks, see p. 41 of this issue.—ED.)

E. L. HARKLEROAD, *Secretary*

Hampton Roads Section

V-STOL Aircraft Is Meeting Topic

Basic evaluation of the use of power for V-STOL aircraft was discussed by **George Schairer,** Director of Research, Boeing Airplane Co., at a recent meeting.

Relying heavily on the use of thrust/weight versus velocity requirements for a jet transport (Boeing 707), Mr. Schairer pointed out the relative effects of increasing power, deflecting jet flaps, and rotating power plants downward. He summed up with the conclusions he felt could be drawn from such a study.

JOHN M. EGGLESTON, *Secretary*

Major Robert Crawford, Staff Intelligence Officer, Air Force Test Center, Edwards AFB, spoke at the February 6th meeting of the Los Angeles Section on "The Rise of Soviet Air Power." Besides discussion of the subject, Major Crawford presented a Russian film and slides which gave an excellent review of current Soviet Air Force development.

New Mexico Section

Colonel Dane Is Speaker at Inaugural Meeting

The inaugural meeting of the New Mexico Section was held on February 17. Members and guests were welcomed by E. W. Robischon, Western Region Manager of the Institute of the Aeronautical Sciences. Mr. Robischon gave a brief outline of the purpose, service, and activities of the IAS, including the advantages of membership.

Colonel Paul H. Dane, Professor and Head of the Thermodynamics Department, U.S. Air Force Academy, addressed the group on the subject, **"Looking Toward Space Horizons—A Mission of the Air Force Academy."**

Colonel Dane's first area of discussion outlined the scientific and military value of satellites. Among these he mentioned distance measurement, weather reconnaissance, terrestrial magnetic field measurements, astronomical observations, and the technique of transmitting observations to land-based stations. Satellites are a necessary medium to explore the problems of sustaining a man in space and getting him back alive. Satellites for strictly military use are limited at the present time to reconnaissance and weather observations. The principal purpose, he said, for launching extra large satellites at this stage of the art is considered justifiable only from the propaganda standpoint.

Colonel Dane then discussed organization of the curriculum at the Air Force Academy. He said the principal purpose is to graduate Air Force career officers,

and in this regard the curriculum differs from ordinary engineering schools in that a considerable number of courses in the humanities are included, in addition to the usual technical subjects. Colonel Dane presented and gave a running discussion of a number of slides showing the extensive facilities at the Academy.

His concluding topic was a plea for additional training of high school students. He advocated the separation of prospective college students from those who do not anticipate attending college.

Officiating at this meeting were the temporary officers, as follows: Alan Y. Pope, Chairman; Harry L. Gogan, Vice-Chairman; Lt. Col. L. T. Boatwright, Secretary; and Warren H. Curry, Treasurer.

Messrs. William Keeler and Lawrence D. Jewel, of the Program Committee, made the arrangements for this meeting.

LT. COL. L. T. BOATWRIGHT, JR., USAF
Secretary

Head-table line-up at the February 19th dinner meeting of the New York Section, held at Grumman Aircraft Engineering Corp., included (*left to right*) R. M. Woodham of Flight Safety Foundation and Secretary of the New York Section; and the following—all from Grumman—Alden L. Rogers, Project Aerodynamicist; A. James Zusi, Chief Aircraft Engineer; Fred C. Rowley, Director, Flight Test Division; Richard Hutton, Chief Aircraft Engineer; Robert Gustafson, Chief of Aerodynamics and Chairman of the New York Section; Oscar Olsen, Manager of Avionics; Kenneth Douglas, Commercial Sales.

New York Section

300 Attend Meeting on Grumman Gulfstream

The Grumman Gulfstream Executive Transport was the subject of the February 19th meeting at which Grumman Aircraft was host to 300 members. Speakers were **Alden Rogers,** Project Aerodynamicist; **Fred Rowley,** Director of the Flight Test Division; and **Henry Scheibel,** Sales Manager—all of Grumman Aircraft.

Mr. Rogers and Mr. Rowley, who used slides and a short movie, provided the following facts: The Gulfstream Transport is one of the new high-speed pressurized turboprop planes for business or light transport use. Its capacity as an executive plane is ten passengers, and as a transport about 19. It has a speed of 350 m.p.h., is highly maneuverable, is equipped with all convenience features necessary for a transport of this type, and has a range in excess of 2,000 miles with normal tanks.

Mr. Scheibel revealed that approximately 30 orders have been placed with Grumman, and, as a result of market research, they look forward to building a substantial quantity of these aircraft. He said that special interior arrangements and radio and navigational installations will be made by distributors to the requirements of the purchaser.

One of the first transports off the production line was available for inspection.

R. M. WOODHAM, *Secretary*

Niagara Frontier Section

NASA, Bell Aides Speak

Members learned about VTOL and STOL research in the United States from a talk by **Robert O. Schade,** Langley Research Center, NASA, at the February meeting. Mr. Schade presented a summary of aircraft capable of VTOL or STOL operation and a discussion of configurations which included propeller, ducted fan, turbojet, and rotor (non-helicopter) types. In addition to classification by power-plant type, he illustrated the various methods utilized in accomplishing transition between hover and conventional flight. He not only emphasized the development of testbeds, prototypes, and research aircraft, but also covered the VTOL-STOL research program of the NASA. A film illustrating the various programs was shown. (Lee Landphair, Committee Chairman for the meeting, introduced Mr. Schade.)

▶ That the rocket-boosted glider has a significant role as a space vehicle was contended at the January meeting by **Dr. Everett T. Welmers,** Assistant for Long-Range Planning to the President, Bell Aircraft. Dr. Welmers described the many uses to which such a vehicle could be put; these included atmospheric research, recoverable satellites, relay and supply to space stations, and use in planetary exploration. Also described were the many problems associated with the development of the glider, and possible solutions were outlined. The concept, he said, was considered feasible, and early development of a practical system is expected.

EDWARD Y. SING, *Secretary*

San Antonio Section

Aeromedical Group Is Discussed

Speakers at the February dinner meeting were **Lt. Col. Joseph A. Bloomer,** Commander, 14th Aeromedical Transport Sq. (MATS), and **Major Clyde Hansen,** Air Evacuation Control Officer for the 14th Aeromedical Transport Sq. Lieutenant Col. Bloomer presented a paper covering the entire activities of the 1st Aeromedical Group; Major Hansen presented one on the medical aspects of the Group's mission.

Lieutenant Col. Bloomer began by quoting the Group's slogan, "We Fly the Armed Force's Most Precious Cargo." That "most precious cargo" is comprised of patients of the Department of Defense, and any other patients as directed.

Specifically, the Group's mission is to provide, maintain, and develop a medically acceptable air transport system for the safe and expeditious movement of patients of the Department of Defense as medically indicated and to maintain, in being, the ability to provide air transportation in support of war plans, or as otherwise directed. The history of the Group, with its five squadrons, and the history of aeromedical evacuation in general, were discussed. This was followed by a description of the type of aircraft in use and the route pattern covered.

Major Hansen then proceeded to discuss, in detail, the wide variety of injuries that could be handled and just how patients are taken care of on board the flying "hospital ward," Convair's C-131 "Samaritan."

He said that the 14th Aeromedical Transport Sq. had a record that their Group Commander, Col. L. B. Matthews, may well be proud of—19,000 accident-free flying hours, operating from all types of fields, plus a 99 per cent patient pickup on time.

In accomplishing its mission, the Group —the only unit of its kind in the Air Force—has averaged a take-off or landing somewhere in the nation every 9 min. of each day and logged some 205,000 flying hours without a major accident, setting a flying safety record often cited by the Air Force.

Following the meeting, members and guests were conducted on a tour of a static display of one of the Group's aircraft, its allied support equipment, and operating personnel.

ROBERT R. PERRY, *Secretary*

The head table of the January 5th inaugural meeting of the South Florida Section included (*left to right*) Col. H. J. Halberstadt, Patrick AFB; Section Program Chairman E. L. Eveleth, Southeast Machinery Co.; Guest Speaker Dr. Igor I. Sikorsky, Sikorsky Aircraft; Section Chairman Prof. John D. Gill, University of Miami; Mayor John V. Russell of Fort Lauderdale; Col. Seth J. McKee, Homestead AFB; A. F. Persons, G-E (St. Petersburg); Comdr. J. W. Williams, Coast Guard Air Station, Dinner Key; C. A. Blaney, The Martin Co.; Col. G. W. Peterson, Palm Beach AFB; Section Vice-Chairman James Addison; Section Treasurer Robert Phillips; and Rev. John C. Updegraff of Fort Lauderdale.

San Francisco Section

Professor of Astronomy Talks About Space Travel

A history of space flight from the mythical Greek figures Daedalus and Icarus to an up-to-date discussion of the environments of planets was presented by **Dr. Samuel Herrick,** Professor of Astronomy, University of California, in his talk on **"Interplanetary Navigation"** at the February meeting.

Professor Herrick presented interesting scientific highlights concerning early prominent astrodynamicists and illustrated his discussion of postulated environments of various planets with appropriate Chesley Bonestell interpretations.

He said that certain rule-of-thumb concepts are helpful in making quick astronautical deductions. For example, a vehicle launched from the earth at 5 m.p.s. will go into a circular orbit; at 7 m.p.s., it will create a hyperbolic orbit; and at 10 m.p.s., escape from the solar system is possible.

Professor Herrick said further that the equatorial "bulge" of the earth causes regression of vehicles orbiting around it. And if, on a trip to the moon, one were counting on gaining energy from the moon as he passed around it, the largest gain possible would be 1.2 m.p.s.

On the other hand, he said, if the trip to Venus were contemplated, a minimum trip time of 146 days should be anticipated. During this period, the space passenger would have traveled 50 million miles. At his destination, the passenger would approach the Venusian atmosphere at a velocity of 6.5 m.p.s., at which point, Professor Herrick declared, the astrodynamicist's responsibility ends.

N. R. BERGRUN, *Secretary*

Seattle Section

Operational Aspects of Supersonic Flight Reviewed

An intriguing look into the future of air travel was provided by **Maynard L. Pennell,** Chief Engineer—Transport Division, Boeing Airplane Co., in his talk on **"Operating the Supersonic Transport"** at the February meeting. The audience was taken on a hypothetical trip from Paris to New York in a supersonic airliner capable of traveling at a Mach Number of 3.0. Mr. Pennell said that the level of comfort, reliability, and safety for this new generation of airplanes could be expected to be at least as good as that of the subsonic jets of today. He said the only really new experience for passengers would be the greatly reduced travel time.

A discussion of changes required in flight planning technique included specific references to cruise altitudes, climb procedures, fuel requirements for cruise and reserve, and procedures and allowances for emergencies such as cabin decompression.

Mr. Pennell indicated that, while the crew of the airliner would have about the same number of jobs to do in preparation for and during the flight, the time available for doing them would be greatly decreased. He said there was a need for more automatic devices in such a situation, with the pilot and flight crew being utilized to monitor the general situation, to analyze unusual situations and make required changes, and to take over when automatic means fail. However, even though increased use is made of automatic devices, the belief was expressed that adequate manual flight controls would be available for back-up purposes and to maintain a minimum level of pilot proficiency.

The enroute cruise operational requirements were discussed, and it was noted that navigation, messages to and from the aircraft, collision avoidance, and other crew duties would be handled largely by automatic devices.

As the flight approaches the destination, the usual preparations and procedures must be initiated, with the emphasis again on automatic devices to accomplish the required tasks because of the limited time available. The critical nature of the descent and the dependence on direct and immediate terminal clearance procedures was discussed with reference to the large fuel requirements, particularly for the less than optimum flight conditions which could result from delays in terminal clearance information.

The landing approach and touch-down would probably be handled manually by the pilot if the weather is good, to maintain proficiency. Reliance on automatic devices in bad weather may be more desirable, with the pilot monitoring the overall situation and taking over manually in the event of a malfunction.

The problems of scheduling a fleet of four supersonic transports by an airline were outlined, and it was shown that such a fleet flying the New York - Paris schedule could probably provide a utilization of $7\frac{1}{2}$ hours per day. The layover periods could be used for progressive maintenance of the airplanes. The possibility of raising the utilization to 9 hours per day by including a New York - Miami schedule for the fleet was mentioned.

Mr. Pennell concluded that the supersonic transport could be scheduled to provide good daily utilization even with the small fleets which may be used when it first goes into service. He said that as air traffic continues to expand, the larger fleet sizes which can be supported will provide more flexibility of scheduling and improved schedule protection.

LOUIS B. GRATZER, *Secretary*

Tullahoma Section

Space Environment Discussed

Human problems in a zero gravity environment were covered at the March meeting in an informal talk by **Major Edward L. Brown,** Chief, Crew Stations Research Section in the Engineering Psychology Branch, Aero Medical Laboratory, WADC.

Motion pictures were shown of human subjects during unrestrained free-floating in the cabin of a C-131B aircraft during a zero gravity Keplerian trajectory maneuver for periods of approximately 15 sec. duration. The development of human locomotion devices for use in outer space was discussed.

MILTON W. DAVIS, *Secretary*

Washington Section

Three Key Men Review Test Range Facilities

Three key men directly charged with responsibility for the operation of current missile and spacecraft test range facilities and future planning for these facilities spoke at the February 10 meeting.

Francis B. Smith, Chief, Tracking Programs, NASA, acted as Honorary Chairman for the meeting. He reviewed briefly the elements of a global tracking and data acquisition system, some of the current satellite tracking facilities, and future requirements for space tracking stations. Mr. Smith then introduced **Col. Paul T. Cooper, USAF,** Deputy Commander—Air Force Missile Test Center, Patrick AFB, Fla., and **Comdr. Robert F. Freitag, USN,** Pacific Missile Range Planning and Development Officer, Pacific Missile Range Hq., Point Mugu, Calif.

Mr. Smith commented on the facilities required to track and obtain data from a satellite. They are (1) facilities to launch the satellite and insert it in an orbit, (2) electronic and optical tracking facilities, (3) data collection equipment, (4) communication and data transmission facilities, (5) computing facilities to provide ephemerides and data reduction.

As examples of these facilities, he showed a map of the current Minitrack stations which are operated by NASA and a photograph of the Goldstone Antenna, an 85-ft. parabolic tracking antenna, located in California. He also presented a map of additional stations required to provide satisfactory tracking of satellites in north-south orbits and the additional stations desired for better tracking of east-west orbits. Concluding his discussion, Mr. Smith showed that deep space tracking coverage could be provided by three stations 120 deg. apart on the earth. One of these could be the present Goldstone station in California, with a station in Australia, and a third station in Europe or Africa.

Colonel Paul T. Cooper then discussed the Atlantic Missile Range, which is a test range with over 10 years of operating experience. The Atlantic Missile Range is the free world's largest outdoor testing laboratory, and it can handle a considerable increase in launch rate. The Range is a center of the Air Force ARDC, which supports testing programs for the Army, Navy, Air Force, and NASA.

There is a seaport at Cape Canaveral, and there are 17 stations of various types on the U.S. mainland. The Range extends down to Ascension Island with its eleven off-shore stations located on islands in the Caribbean and Atlantic. Ascension Island is 4,400 nautical miles from Cape Canaveral. Gaps in the island stations are filled by twelve instrumentation picket ships. These ships are also used to extend the test range beyond Ascension Island so that the intercontinental missiles can be flown to their full operational ranges. There are 128 receiving antennas for telemetered data on the range. As many as 65 cameras are used on a single missile flight to gather data, and useful photos have been taken from distances of over 150 miles. Missiles have been tracked 3,400 miles, and the Air Force lunar probe was tracked to a distance of more than 30,000 miles. The Atlantic Missile Range instruments 1.5 million square miles, an area equal to half that of the U.S. In the past 3 years, with the build-up of the ballistic missile programs, approximately a billion dollars has been spent to develop the test range.

Colonel Cooper showed photographs of the down range stations, instrumentation sites, missile launching facilities, and finally a film of the significant achievements in 1958. Introducing the film, Colonel Cooper said the public has had a lesson to learn—that we get data by failing. There has been much emphasis on this lesson which has been fairly well learned. The film presented the achievement milestones of 1958: The Army Explorer I on January 31 which is still in orbit; the Vanguard on March 17 which is in orbit with a 2,400-mile apogee and still trans-

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AERO/SPACE ENGINEERING

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Governor Joe Foss, Preston Dixon, who arranged the speaking engagement, and Vice-Chairman Howard Smith discuss the Governor's speech just prior to the February meeting of the Wichita Section.

mitting with power from a solar battery; the Thor Able with the mouse which traveled 5,500 miles; a Snark missile which went over 5,000 miles; the Thor lunar probe on October 11; a double BOMARC firing on October 21; an Atlas on November 28 to a range of over 5,500 nautical miles; the Juno II sponsored by NASA on December 6; and the Atlas 10B on December 18 which put almost 4 tons in orbit and from which the President's voice was broadcast.

Colonel Cooper concluded that the Atlantic Missile Range experience will be applied in future programs, and, as our objectives grow, the Atlantic Missile Range will grow.

Next, Comdr. Robert F. Freitag, speaking on the Pacific Missile Range, was introduced. The Pacific Test Range began with the Naval Air Missile Test Center in 1945 which provided test facilities for Navy air-to-air, surface-to-air, and surface-to-surface missiles. In 1956, when the tremendous ballistic missile program build-up was under way, there was concern as to whether or not the Atlantic Missile Range would be adequate, so the Pacific Missile Range was given the role of providing extensive training operations in an operational environment. Vandenburg AFB is located at the Pacific Missile Range, and it can be used to fire ICBM's against an enemy. The Pacific Missile Range will evaluate the training operations run from there. For the future it is concerned with the problems of a long-term space program.

Commander Freitag said the Pacific Missile and Atlantic Missile Ranges differ in that only the launch area and the terminal area will be instrumented for the operational exercises to be conducted. For the most part, the missiles will be proved, and the extensive continuous instrumentation used on the Atlantic Missile Range will not be required. The Pacific Missile Range has clear-water area to the south so that satellites can be launched into polar orbits without passing over populated land area in the launch phase. It also has advantages in launching satellites into equatorial orbits which are required if stationary satellites are to be established. The Pacific Missile Range will fit into a logical overall global system to support a U.S. program to gain space supremacy in the world.

He then showed a map of the range facilities, Vandenburg AFB, Point Arguello, the mountains which protect the mainland areas from sound and safety standpoints, and nearby highways and railroads. Several attractive slides of the facilities under construction and the nearby areas were shown.

Ballistic missile firings will be generally to the south. The sea test range will continue to support Navy missile programs, but this will not interfere with ballistic missile and space operations. The first space firing from the Pacific Missile Range will take place in the near future with the launching of the Discoverer satellite. The first instrumentation picket ship is now on station. Equatorial orbit satellite launch planning is under way.

In conclusion, Commander Freitag said that the U.S. has the ability to develop the Air Traffic Control of the space age. The Soviets do not have this opportunity because of geographical limitations. It will take an estimated $1 billion to develop the Pacific Missile Range over the next 5 to 10 years. If a global space system is developed, it will require a national investment in facilities around the earth which is on the order of $2 to $3 billion. The Pacific Missile Range is planned to provide a large over-water range which will support long-range air-to-air missile tests, long-range air-to-surface missile tests, extended-range surface-to-air missile tests, ICBM and AICBM training, nuclear-propelled missile testing, satellite launchings in polar and equatorial orbits, and deep space operations.

QUENTIN J. GOSS, *Secretary*

Wichita Section

Ex-Governor Foss Is Guest Speaker

Joe Foss, Ex-Governor of South Dakota, spoke to some 250 members and guests at the February meeting on **"The Importance of Aviation and Space Technology as an Instrument of Military, Social, Economic, and Political Welfare."**

Governor Foss reviewed the history of aviation from prewar years up to the present and showed why aviation is now important in our everyday life. He then presented his ideas on how space technology is now and can be of increasing importance in everyone's daily life and future.

Governor Foss is a Marine war "ace" and a recipient of the Congressional Medal of Honor. He is a Brigadier General in the USAF Reserve.

R. S. HAGAN, *Secretary*

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IAS SCRIP COUPONS may now be used as payment for preprints, dues, subscriptions, and all other IAS services. This method will save you from writing checks, sending money orders or cash. Sheets of 5- and 25-cent coupons are available in book form of $5, $10, $25, or any amount desired, from the Special Publications Dept. Scrip may be ordered by foreign and domestic members and nonmembers.

REVIEWS OF *Books*

. . . in the field of aeronautical engineering and space technology

AERONAUTICS, GENERAL

Plans for Low-Cost Pole-Type Hangars. Donald Patterson. Chicago, American Wood Preservers Institute, 1959. 14 pp., designs and plans. $3.00.

AVIATION MEDICINE, SPACE MEDICINE

The Beginnings of Research in Space Biology at the Air Force Missile Development Center, Holloman Air Force Base, New Mexico, 1946–1952. David Bushnell. HAFB, N.M., AFMDC ARDC, 1958. 36 pp.

Major Achievements in Space Biology, at the Air Force Missile Development Center, Holloman Air Force Base, New Mexico, 1953–1957. David Bushnell. HAFB, N.M., AFMDC, ARDC, 1958. 17 pp., illus.

History of Research in Subgravity and Zero-G, at the Air Force Missile Development Center, Holloman AFB, New Mexico, 1948–1958. David Bushnell. HAFB, N.M., AFMDC, ARDC, 1958. 45 pp.

Major Achievements in Biodynamics: Escape Physiology, at the Air Force Missile Development Center, Holloman Air Force Base, New Mexico, 1953–1958. David Bushnell. HAFB, N.M., AFMDC, ARDC, 1958. 56 pp., illus.

Research Accomplishments in Biodynamics: Deceleration and Impact, at the Air Force Missile Development Center, Holloman Air Force Base, New Mexico, 1955–1958. David Bushnell. HAFB, N.M., AFMDC, ARDC, 1958. 67 pp., illus.

COMBUSTION

Combustion and Propulsion, Third AGARD Colloquium: Noise, Shock Tubes, Magnetic Effects, Instability and Mixing; Including Four Selected Papers Presented at the Washington AGARD Meeting. Edited by M.W. Thring, O. Lutz, J. Fabric, and A. H. Lefebvre. (*Combustion Colloquium, Palermo, Sicily, March 17–21, 1958.*) New York; London, Pergamon Press, 1958. 614 pp., illus., diagrs., tables. $20.

Contents: Preface, Th. von Kármán. *Introduction*, J. Ducarme. *Part I:* Power Plant Requirements Related to Aircraft Missions. Development Problems in Large Liquid Rocket Engines, R. S. Levine. Propulsion by Air Breathing Engines, A. A. Lombard. *Part II:* Interaction of Combustion Systems with Other Engine Components. Effects on Turbojet Combustors and Afterburners of Other Engine Components, J. H. Childs. Le Problème du Stato-Fusée, E. Le Grivzs. Recent Work on Mixing at the Polytechnic Institute of Brooklyn, L. G. Napolitano, P. A. Libby, and A. Ferri. Shock Wave and Flame Interactions, G. Rudinger. *Part III:* Noise. Jet Engine Noise Reduction, N. D. Sanders and W. J. North. Some Thoughts on Noise Suppression Nozzle Design, E. J. Richards. L'Insonorisation des Bancs d'Essais de Moteurs d'Aviation: Aspects Techniques, Financiers et Physiologiques, P. Ducrot, A. Riehn, C. Roumilhac, and H. Souvras. *Part IV:* Combustion. Some Thoughts on Flame Theory, D. B. Spalding. Review of Some Recent Combustion Experiments, M. Gerstein. Rôle des Recherches Fondamentales dans l'Étude des Foyers d'Aviation, C. Fouré. Studies of the Decomposition Mechanism, Erosive Burning, Sonance and Resonance for Solid Composite Propellants, R. Schultz, L. Green, Jr., and S. S. Penner. *Part V:* Aerophysical Chemistry. Radiation Heat Transfer to Hypersonic Vehicles, R. E. Meyerrott. Convective Heat Transfer with Mass Addition and Chemical Reactions, L. Lees. High Temperature Shock Waves, O. Laporte. On Magneto-Fluid-Dynamics, A. Schlüter. *Part VI:* Twelfth Meeting of the AGARD Combustion and Propulsion Panel—Selected Papers. A Review of Flame Stabilization by Means of Gaseous Jets, A. B. Cambel. Étude d'un Procédé Aérodynamique de Combustion, J. Bertin and B. Salmon. Flame Stabilization in Boundary Layers, Tau-Yi Toong. Graphical Method on Problems of Gasdynamic Mixing, O. Lutz. *Index.*

DICTIONARIES

Russian-English Glossary of Optics and Spectroscopy. Edited by I. Emin; Compiled by Sonia Noveck. New York, Interlanguage Dictionaries Publishing Corp., 1959. 78 pp. $10.

This glossary contains over 4,000 terms taken from numerous articles appearing in the most recent issues of related Soviet journals, especially *Optics and Spectroscopy*, the *Journal of Technical Physics*, *Journal of Experimental and Theoretical Physics*, and the physics section of the *Doklady* of the Academy of Sciences of the U.S.S.R. Also included in this work are many terms and expressions found in original Russian texts, and in English texts which have been translated into Russian.

Dictionary of Astronomy and Astronautics. Armand Spitz and Frank Gaynor. New York, Philosophical Library, 1959. 439 pp. $6.00.

The dictionary contains more than 2,200 concise definitions of terms and concepts related to astronomy and astronautics. The purpose has been to produce a previously unavailable reference book on the dynamic terminology of the advancing field of astronautics, which includes terms both old and new.

Dr. Spitz is Coordinator of Visual Satellite Observations for the Smithsonian Astrophysical Observatory, Cambridge, Mass.; Mr. Gaynor is a Contributing Editor to the *Encyclopedia Britannica*.

EDUCATION

Engineering Enrollment in the United States. Edited by Norman N. Barish. New York, New York University Press, 1957. 226 pp., charts, tables. $7.50.

The purpose of this volume is to present basic statistics on enrollment trends in engineering education in the United States; to suggest some possible interpretations of these trends; to promote comparisons of enrollment trends in individual schools with those in the entire nation; and to provide some basis for forecasting future conditions. A chapter on engineering education in the U.S.S.R. has also been included, to place our corresponding program in clearer perspective. The principal conclusion of the Editor is that we need to concentrate more on qualitative needs for engineers, rather than quantitative, and, to meet this need, he proposes a new pattern for engineering education.

Contents: (1) Growth of Engineering Education in the United States, N. N. Barish. (2) Engineering Enrollment in the United States, N. N. Barish. (3) Enrollment Outlook for the Future, N. N. Barish. (4) Engineering Education and Manpower Requirements, N. N. Barish. (5) Enrollment Trends in the Various Engineering Specialties, N. N. Barish. (6) Aeronautical Engineering, S. P. Johnston. (7) Agricultural Engineering, L. J. Fletcher. (8) Architectural Engineering, R. Walker. (9) Ceramic Engineering, R. E. Birch. (10) Chemical Engineering, T. H. Chilton. (11) Civil Engineering, H. G. Dixon. (12) Electrical Engineering, A. C. Monteith and G. E. Moore. (13) Engineering Science (Engineering Mechanics and Engineering Physics), M. Goland. (14) Geological Engineering, H. A. Meyerhoff. (15) Industrial Engineering, C. E. Bullinger. (16) Mechanical Engineering, J. Barker. (17) Metallurgical Engineering, H. K. Work and J. P. Nielsen. (18) Mining Engineering, L. E. Shafffer. (19) Naval Architecture and Marine Engineering, F. E. Haeberle. (20) Petroleum Engineering, M. T. Carpenter. (21) Sanitary Engineering, M. D. Hollis and H. F. Ludwig. (22) Textile Engineering, L. A. Runton. (23) Engineering Training in Russia, M. H. Trytten.

ELECTRICAL ENGINEERING

The Theory and Design of Magnetic Amplifiers. E. H. Frost-Smith. (*Automation and Control Engineering Series. Edited by John F. Coales.*) New York, John Wiley & Sons, Inc., 1958. 487 pp., illus., diagrs., tables. $12.50.

Dr. Frost-Smith presents an account of the theory of magnetic amplifiers which relates theory to design. Many of the theoretical aspects are supplemented by short numerical examples. A number of complete designs are carried out in one of the chapters, and some typical problems to which magnetic amplifiers have been applied successfully are included in another.

The author, Director of Research, the Staveley Coal and Iron Co., Ltd., has arranged his material to be of use both to the professional engineer and the university student.

ELECTRONICS

Semiconductor Abstracts; Abstracts of Literature on Semiconducting and Luminescent Materials and Their Applications, Vol. 4, 1956 Issue. Edited by E. Paskell. Compiled by Battelle Memorial Institute; Sponsored by the Electrochemical Society, Inc. New York, John Wiley & Sons, Inc., 1959. 456 pp. $12.

Contents: Germanium: Purification and Crystal Growth; Impurities; Lattice Defects; Band Structure; Conductivity and Mobility; Photo Effects and Optical Properties; Lifetime and Injection; Surface Recombination and Surface States; Etching; Noise; Junctions and Diodes; Transistors. Silicon: Purification and Crystal Growth; Lattice Defects and Impurities; Band Structure Conductivity, and Lifetime; Surfaces and Breakdown; Diodes and Transistors. Carbon, Selenium, and Other Elemental Semiconductors: Carbon and Graphite; Diamond; Selenium; Antimony, Bismuth, Gray Tin, and Tellurium. Intermetallics: Aluminum, Cesium and Gallium Antimonide; Indium Antimonide; Arsenides, Phosphides and Stannides; Carbides, Nitrides, Silicides, and Borides. Sulfides, Selenides, and Tellurides: Cadmium Sulfide; Zinc Sulfide; Lead Sulfide; Other Sulfides; Selenides; Tellurides. Oxides: Barium Oxide and Oxide Cathodes; Copper Oxide; Other Oxides. Halides: Sodium Halides; Potassium Halides; Silver Halides; Other Halides. Arsenates, Phosphates, Silicates, and Tungstates. Organics. Theory: Crystal Growth and Imperfections; Band Structure; Conductivity and Mobility; Hall and Magnetic Effects; Lifetime Surface Effects, and Noise; Thermal and Photo Effects; Contacts, Junctions, Rectifiers, and Transistors; Luminescence; *Reviews and Books. Author Index. Subject Index.*

FLUID MECHANICS

Advanced Mechanics of Fluids. Edited by Hunter Rouse. New York, John Wiley & Sons, Inc., 1959. 444 pp., diagrs., tables. $9.75.

This advanced presentation on fluid mechanics is a sequal to *Elementary Mechanics of Fluids* which was issued in 1946. Consisting of contributions by various authors, the eight chapters deal with: research in fluid motion, fundamental concepts and equations, principles of irrotational flow, conformal representation of two-dimensional flow, laminar motion, turbulence, boundary layers, and free-turbulence shear flow. Primary emphasis of the material is on the theoretical approach, and the format of the book is oriented to fill the function of a text both for formal classes and for self-instruction.

The authors (H. Rouse, D. W. Appel, P. G. Hubbard, L. Landweber, E. M. Laursen, J. S. McNown, T. T. Siao, A. Toch, and C. S. Yih) are all members of the staff of the Iowa Institute of Hydraulic Research, State University of Iowa.

GLIDING

Gliding; A Handbook on Soaring Flight. Derek Piggot. New York, The Macmillan Company, 1958. 261 pp., illus., diagrs. $5.00.

In this comprehensive guide to soaring flight, the Chief Flying Instructor at the Lasham Gliding Centre furnishes the novice pilot with the theoretical knowledge which, in conjunction with flying experience, will enable him to complete his first solo flights and qualify for certificates of competence.

Contents: Section I. Learning to Glide: First Flights in a Glider; Launching Procedure; The Effects of the Controls; Turning; The Take-Off and the Launch; The Approach and Landing; Stalling and Spinning; Circuit Procedure; Cable Breaks; Rules of the Air. *Section II.* Further Training and Soaring: More about Turning; Sideslipping; Better Launches; Landing out of Wind; More about Stalling and Spinning; Safe Flying in High Winds; Launching by Aerotow; Local Soaring and Efficient Cruising. *Section III.* Exploring the Skies: Thermals; Thermal Soaring; Hill Soaring; Wave Soaring; Landing in Strange Fields; The Instruments and their Limitations; Instrument Flying; Flying High; Finding your Way in the Air; Going Faster and Farther. *Appendix 1:* Gliding Awards and Records. *Appendix 2:* The Gliding Movement in Great Britain. *Appendix 3:* Owning your own Glider. *Index.*

MATERIALS

Fundamentals of High Polymers. O. A. Battista. New York, Reinhold Publishing Corporation, 1958. 140 pp., illus., diagrs., tables. $5.50.

The present text covers every important area of high-level polymer science, and, with its exten-

sive bibliography of the published literature, should prove useful to persons requiring a basic knowledge of this vast field. The opening chapter consists of basic terms and definitions, followed by chapters on: the basic chemistry of all of the major natural and man-made high polymer products, the formation of useful macromolecular products and details of their architecture, the measurement of both the solution and solid state properties of high polymers, and also their physical properties as related to specific end uses.

O. A. Battista is with the Research and Development Division, American Viscose Corporation.

Processing of Thermoplastic Materials. Edited by Ernest C. Bernhardt. (*Society of Plastics Engineers, Inc. The Plastics Engineering Series, Vol. 2.*) New York, Reinhold Publishing Corporation, 1959. 690 pp., illus., diagrs., tables. $18.

The purpose of this book is to review the engineering fundamentals on which the design of plastics processing equipment is based, and to demonstrate the practical application of these fundamental concepts in the analysis of extrusion, injection molding, calendering, and other thermoplastics processing problems. The volume has been designed to fill the need for a basic textbook on the subject, and consists of the contributions of experts in the various branches of the field. Previous knowledge in plastics processing technology is not necessary in using the text.

Dr. Bernhardt is with the Polychemical Department, E. I. du Pont de Nemours & Co., Inc.

MATHEMATICS

Introduction to the Problem of Minimal Models in the Theory of Algebraic Surfaces. Oscar Zariski. (*Publications of the Mathematical Society of Japan, No. 4.*) Tokyo, The Mathematical Society of Japan. 1958. 89 pp.

The present monograph is based on a series of lectures given by the author at the University of Tokyo and the University of Kyoto in September and October, 1956, during his visit as guest lecturer of the Science Council of Japan.

Contents: I. Rational Transformations of Algebraic Varieties. *II.* Theory of Exceptional Curves on an Algebraic Surface. *III.* The Problem of Minimal Models for Algebraic Surfaces.

MILITARY AVIATION

The Air Forces of the World; Their History, Development and Present Strength. William Green and John Fricker. New York, Hanover House, 1958. 336 pp., illus., maps. $10.95.

This comprehensive work, which details the disposition of the world's air power, serves as a reference and guide to the strength, equipment, bases, and organization of every air arm in existence today. Using more than 500 photographs, the book presents a history of the development of military aviation in each country, with a listing of the aircraft types employed; a color section of international military insignia; a group of maps showing the principal air bases of every nation; and many previously unpublished photographs of representative aircraft equipment which illustrate virtually every type of military airplane in existence. The index serves as a guide to every photograph of a plane that appears throughout the text.

NUCLEAR ENERGY

Research on Power From Fusion and Other Major Activities in the Atomic Energy Programs, January–June, 1958. U.S. Atomic Energy Commission. Washington, Superintendent of Documents, July, 1958. 410 pp., illus., diagrs., tables. $1.25.

Contents: Part One: Major Activities in the Atomic Energy Programs: Raw Materials; Production of Special Nuclear Materials; Military Applications; International Activities; Commercial and Isotope Development; Licensing, Regulation, Indemnity; Inspection; Reactor Development; Classification and Declassification; Information Activities; Education and Training; Physical Research; Biology and Medicine; Nuclear Materials Management; Construction and Supply; Community Activities; New Headquarters; Organization and Personnel.

Part Two: Progress Toward Producing Power from Controlled Fusion. (1) The Commission Program of Controlled Thermonuclear Research. (2) The Goals and the Problems. (3) Pinch Program. (4) Stellarator Program. (5) Magnetic Mirror Program. (6) High Energy Injection. (7) Other Research Programs.

Appendixes: Organization and Principal Staff of U.S. Atomic Energy Commission; Membership of Committees; Major Research and Development Installations of the U.S. Atomic Energy Commission; Radioactive Isotope Distribution Data, Oak Ridge, Tenn.; Commission-Owned Patents; Publications of the U.S. Atomic Energy Commission; Regulations of the U.S. Atomic Energy Commission; License and Access Permits Applications Filed and Actions Taken; Nuclear Reactors Built, Building, or Planned in the United States as of June 30, 1958; Health and Safety Precautions for Eniwetok Proving Ground Tests; A Report on the Domestic Mining and Milling Problems; Remarks Prepared by Dr. Willard F. Libby, Commissioner, for Delivery Before the Swiss Academy of Medical Sciences Symposium on Radioactive Fallout, March 27, 1958; Information on Detonations Released for Use in Seismological Studies; The President's Message on International Agreement With Euratom; Memorandum of Understanding Between United States and Euratom; Press Release on Oak Ridge Nuclear Incident.

Atomic Industrial Progress and Second World Conference, July–December, 1958. U.S. Atomic Energy Commission. Washington, Superintendent of Documents, January, 1959. 386 pp., illus., tables. $1.25.

The Twenty-fifth Semiannual Report of the AEC to the U.S. Congress comprises three sections: *Part One* consists of a summary of industrial atomic progress during 1958; *Part Two* contains a description of U.S. participation in the Second World Conference on Peaceful Uses of Atomic Energy; and *Part Three* presents a review of the July–December, 1958, major activities in selected atomic energy programs, which includes a description of the military reactor development program for nuclear propelled aircraft.

PHYSICS OF METALS

Progress in Metal Physics, Vol. 7. Edited by Bruce Chalmers and R. King. New York; London, Pergamon Press, 1958. 408 pp., diagrs., tables. $16.

Contents: (1) Equilibrium, Diffusion, and Imperfections in Semiconductors, J.N. Hobstetter. (2) The Physical Metallurgy of Titanium Alloys, R.I. Jaffee. (3) Thermodynamics and Kinetics of Martensitic Transformations, L. Kaufman and M. Cohen. (4) The Stored Energy of Cold Work, A. L. Titchener and M. B. Bever. (5) The Properties of Metals at Low Temperatures, H. M. Rosenberg. *Contents of Previous Volumes. Name Index. Subject Index.*

POWER PLANTS

Gas Turbines for Aircraft. Arthur W. Judge. New York, The Macmillan Company, 1959. 439 pp., illus., diagrs., tables. $12.

Contents: (1) History and Development. (2) Aircraft Jet Propulsion Engine Development. (3) The Simple Gas Turbine. (4) Some General Considerations. (5) Improving Gas Turbine Performance. (6) Aircraft Gas Turbine Types. (7) The Turbojet Engine. (8) The Turboprop Engine. (9) Fuels and Fuel Systems. (10) The Combustion System. (11) The Lubrication System. (12) Augmented Power. Starting Methods. (13) Failure Causes, Maintenance, Silencing, etc. (14) Special Materials for Gas Turbines. (15) Special Types of Aircraft Engines. (16) Some Thermodynamic Considerations. *Key to Text References and Bibliography. Data and Performances for British Gas Turbines. Data and Performance for U.S. Gas Turbines. Index.*

Heat Exchangers, Applications to Gas Turbines. W. Hryniszak. New York, Academic Press, Inc.; London, Butterworths Scientific Publications, 1958. 343 pp., illus., diagrs., tables. $10.

Sherman M. Fairchild Publication Fund Papers (Order by number from IAS)

No.		Member	Nonmem.
FF-21	Rocket Propulsion Systems for interplanetary Flight—George P. Sutton, 1959 Minta Martin Lecture.	$1.00	$2.00
FF-20	Supersonic Transports Proceedings (Papers and Discussions presented at IAS 27th Annual Mtg. Session).	1.00	2.00
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FF-10	Improved Solutions of the Faulkner and Skan Boundary-Layer Equation—A. M. O. Smith.	0.75	1.25
FF-9	A Hydrodynamic Study of the Chines-Dry Planing Body—Experimental Towing Tank, Stevens Inst. of Tech.	1.20	1.60
FF-7	Natural Flight and Related Aeronautics—James L. G. Fitz Patrick.	2.65	3.50
FF-4	Finite Deflections of Curved Sandwich Plates and Sandwich Cylinders—F. K. Teichmann and Chi-Teh Wang.	0.50	0.85
FF-3	The Penetration of a Fluid Surface by a Wedge—Experimental Towing Tank, Stevens Inst. of Tech.	1.20	1.60
AHS-1	Helicopter Flight Research at NACA, Langley—Jack P. Reeder.	0.35	0.75

No.		Member	Nonmem.
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169	The Discontinuous Fluid Flow Past an Immersed Wedge—Experimental Towing Tank, Stevens Inst. of Tech.	0.75	1.00
168	Wave Contours in the Wake of a 20° Deadrise Planing Surface—Exp. Towing Tank, Stevens Inst. Tech.	1.20	1.60
167	On the Pressure Distribution for a Wedge Penetrating a Fluid Surface—Experimental Towing Tank, Stevens Inst. of Tech.	0.75	1.00
165	Theory and Practice of Sandwich Construction in Aircraft (Symposium).	1.85	2.50
126	External Sound Levels of Aircraft—R. L. Field, T. M. Edwards, Pell Kangas, and G. L. Pigman.	0.75	1.00
106	Measurement of Ambient Air Temperature in Flight—W. Lavern Howland.	0.35	0.50
104	Tensor Analysis of Aircraft Structural Vibration—Charles E. Mack, Jr.	1.85	2.50
102	Electrical Resistance Strain Gages Applied to Wind-Tunnel Balances—Elmer C. Lundquist.	0.60	0.80
101	Introduction to Shock Wave Theory—J. G. Coffin.	2.65	3.50
100	Blade Pitching Moments of a Two-Bladed Rotor—R. W. Allen.	0.75	1.00

This book has been written for the engineer and physicist, and deals not with the process of heat transfer itself but with the apparatus performing this transfer, and with the designing and fitting of it into an economical gas turbine unit. The manner in which the thermodynamical optimization of the gas turbine air preheater has been treated will be of interest in connection with supercritical steam cycles and nuclear power applications.

Mr. Hryniszak is associated with C.A.P. Parsons & Co., Ltd., England, and enjoys an international reputation in the field of thermodynamics.

Contents: (1) Introduction. (2) Types of Gas Turbine Heat Exchanger. (3) Different Ways of Performing Heat Transfer (Recuperators and Regenerators). (4) Principal Thermodynamic Properties of Heat Exchangers. (5) Influence of the Heat Exchanger on the Performance of the Gas Turbine Unit. (6) Influence of the Thermodynamic Properties of an Air Preheater on its Main Dimensions. (7) Design of Recuperative Heat Exchangers. (8) Regenerators. (9) Part Load Performance of an Air Preheater. (10) Influence of the Air Preheater on the Governing of the Gas Turbine Unit. (11) Test Arrangements and Testing. (12) Stresses and Materials. (13) Cost as Affecting the Most Economical Layout of Heat Exchangers. (14) The Question of Weight as Affecting Air Preheaters in Gas Turbine Units for Aircraft and Vehicles. (15) General Design Problems Affecting the Whole Gas Turbine Unit. *Conversion Table. List of Symbols. Index.*

PRODUCTION

Bonded Aircraft Structures; Papers Given in Cambridge at a Conference Arranged by Aero Research Limited, Duxford, Cambridge, in 1957. Duxford, Cambridge, England, CIBA (A.R.L.) Ltd., 1959. 177 pp., illus., diagrs., tables. $7.50.

Contents: Foreword, Sir William Farren. Fundamentals of Adhesion, N. A. de Bruyne. Design Aspects of Bonded Structures 1, O. Ljungstrom. Design Aspects of Bonded Structures 2, E. J. Van Beek. Press Bonding, H. Povey. Autoclave Bonding, N. Evans. Vacuum Table Bonding, D. Winter. Production Tools for 'Redux', R. J. Schliekelmann. Tools for Bonding, H. T. Duffy, Production Bonding with 'Araldite,' C. Thomas. Design and Testing of Honeycomb-Cored Structures, B. R. Noton. Honeycomb-Cored Structures, A. Holt. Bonding of Aircraft Magnesium Assemblies with 'Redux' Adhesives, B. A. Forcht. The Use of 'Araldite' for Making Tools and Glass-cloth Laminating, R. H. Wilson. Inspection of Bonded Aircraft Structures, F. D. C. Jeffery. Inspection and Testing of Honeycomb and Honeycomb Sandwiches, R. F. Blackwell. High-Temperature Adhesives, C. A. A. Rayner.

SAFETY

Danger in the Air. Oliver Stewart. New York, Philosophical Library, 1958. 194 pp., illus., diagrs. $6.00.

Every accident, when properly examined, should be a step towards the elimination of some hazard, according to the author, who argues that the tendency to hush up air accidents or to treat them in a sensational manner is damaging to the development of safe flying. Mr. Stewart, the present editor of *Aeronautics*, describes and comments upon a variety of air accidents occasioned by topographical error, instrumental responsibilities, crew fatigue, "hotel echo" and the weather, control faults, criminal intent, accident at sea, structural failure, icing of airframe and engines, motorless flight, engine failure, pilot error, collision, and fire in the air. Each accident illustrates some particular kind of danger, and the procedures taken by engineers, designers, and research workers to combat it.

STRUCTURES

Proceedings of the Society for Experimental Stress Analysis, Vol. 16, No. 1. Edited by C. V. Malhmann and W. M. Murray. Cambridge, Mass., The Society, 1958. 198 pp., illus., diagrs., $6.00.

Contents: The Determination of Effective Stress and Maximum Shear Stress by Means of Small Cubes Taken from Photoelastic Models, J. S. Brock. Fatigue—Service Life Prediction Based on Tests at Constant Stress Levels, C. R. Smith. Vibration Analysis of a 700-Horsepower Induced Draft Fan, G. A. Brewster. Analog Determination of Generalized Shock Spectra, W. A. Nash and W. A. Hijab. Discussion of the Preceding Paper, C. E. Crede and R. D. Cavanaugh. A Large Mechanical Installation for Duration Tests, L. Baes and Y. Verwilst. Experimental Verification of Mathematically Derived Formulae, E. C. Clark. The Dynamic Stress Distribution Surrounding a Running Crack—A Photoelastic Analysis, A. Wells and D. Post. Discussion of the Preceding Paper, G. R. Irwin. Performance of Foil-Type High-Temperature Strain Gages up to 700°F., E. E. Day. Determination of the Stacking Strength of Corrugated Fiberboard Containers, B. S. Angell and P. R. Paslay. Resistance Network Solution of Some Structural Problems in Deflection and Stability, R.H. Scanlan. Stress Concentration Produced in Perforated Strips Under Tension, P. S. Theocaris. Strain Gage Waterproofing Methods and Installation of Gages on Propeller Strut of U.S.S. "Saratoga," M. Dean, III. Effect of Hydrostatic Pressure on SR-4 Strain Gages, J. P. Guerard and G. F. Weissmann. An Impact Testing Machine for Plastics and Rubber-Like Materials, E. Volterra and C. S. Barton. Discussion of the Preceding Paper, W. F. Riley, A. J. Durelli, and J. W. Dally. Stress and Strength Studies on Turbine Blade Attachments, A.J. Durelli, J. W. Dally, and W. F. Riley. Discussion of the Preceding Paper, P. D. Flynn. Transient Response of Accelerometers, W. G. Soper. Roller Fixtures for Pin-Ended Column Tests, J. E. Goldberg and K. H. Lenzen. Theory for the Calculation of the Tangential Residual Stress Distribution in Curved Beams, J. L. Rembowski.

VIBRATION

A Handbook on Torsional Vibration. The British Internal Combustion Engine Research Association. Compiled by E. J. Nestorides. New York, Cambridge University Press; Cambridge, England. At the University Press, 1958. 663 pp., illus., diagrs., tables. $19.50.

This handbook on torsional vibration is written primarily to provide information in ready reference form for both the professional engineer and the student, and includes new information based on the experiences of the BICERA. Laboratory and its member firms. For the engine designer, the recommended formulas, graphical procedures, numerical examples, and tabulated values are given, and these are followed by remarks regarding the limitations of each method and its mathematical derivation. For the development engineer, descriptions of test procedures, rigs and instrumentation are given in detail, together with remarks regarding precautions against possible sources of error, and the order of accuracy to be expected of the test results.

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The Editor is with the BICERA Research Laboratory and recommends the book as essential information for the mechanical, marine, aero-engine, and automobile engineer; designers of reciprocating engines; instrument, development, and consulting engineers; and stress analysts.

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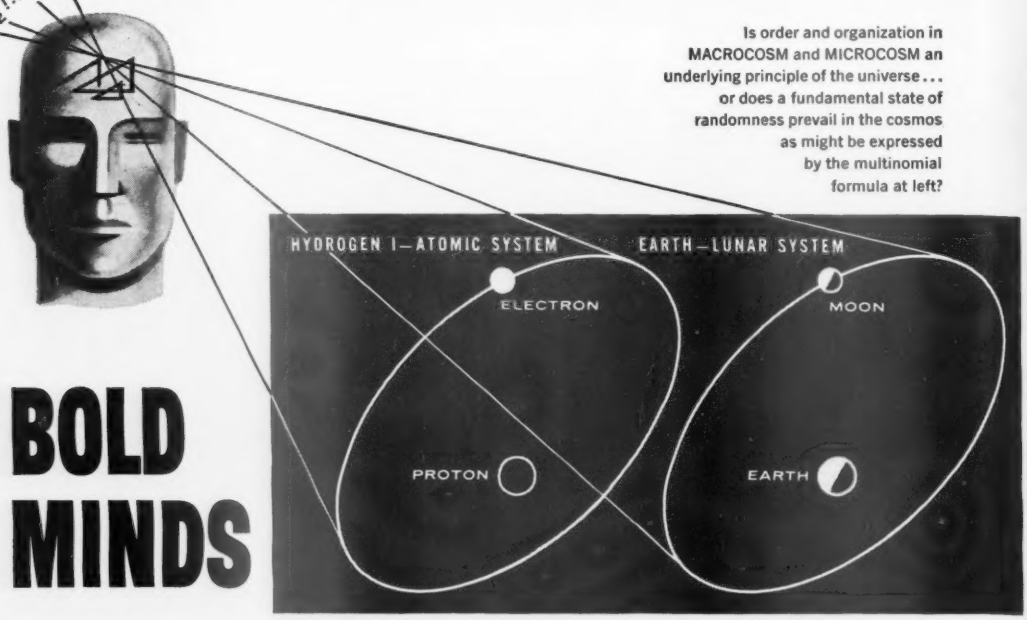

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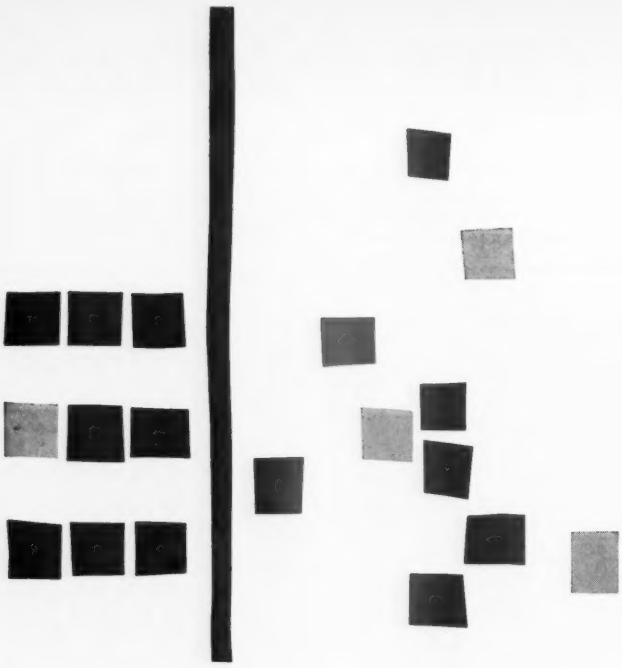

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